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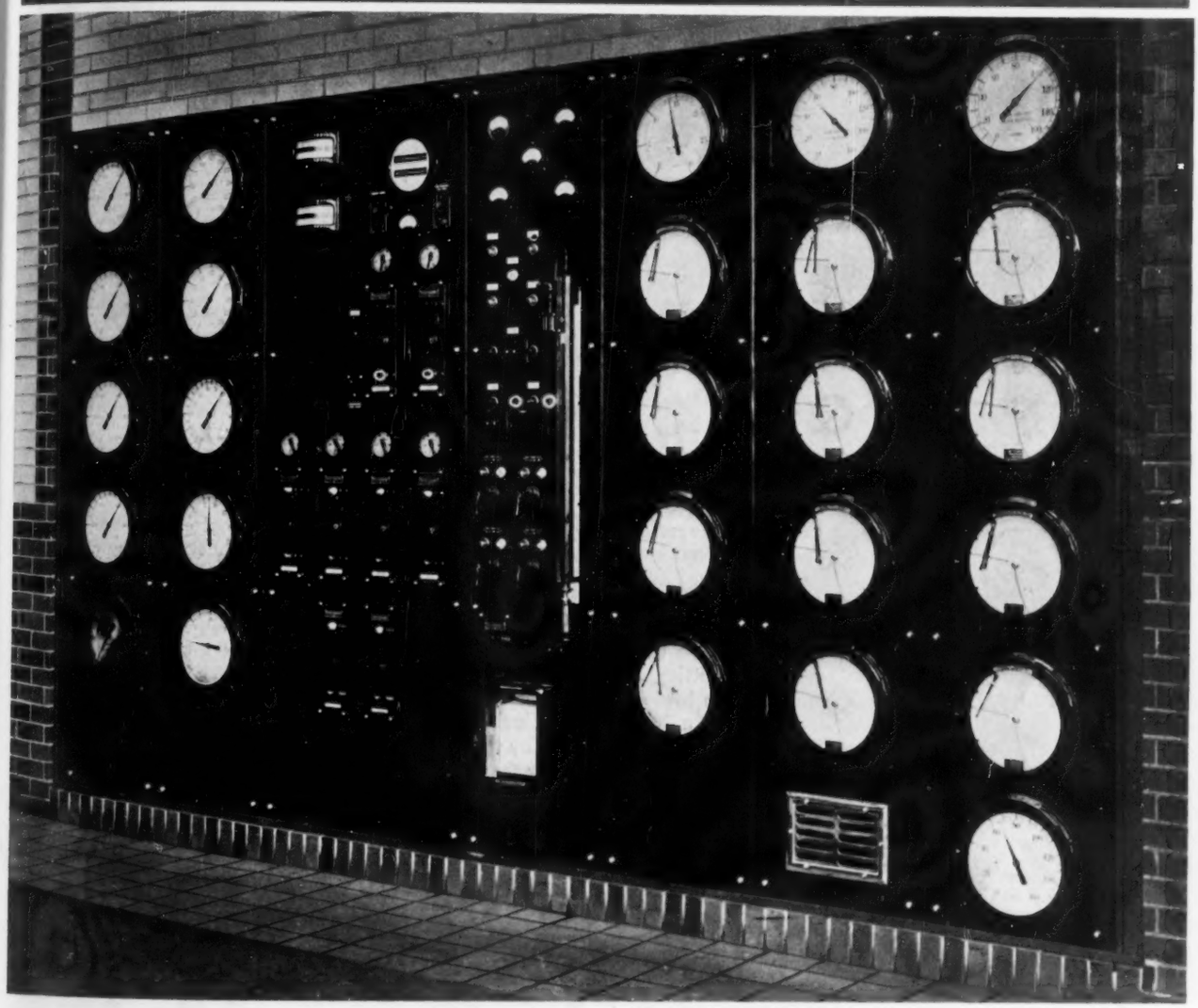
INSTRUMENTS

THE MAGAZINE OF MEASUREMENT AND CONTROL

VOLUME 7 SEPTEMBER, 1934 NUMBER 8



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(See page 177)

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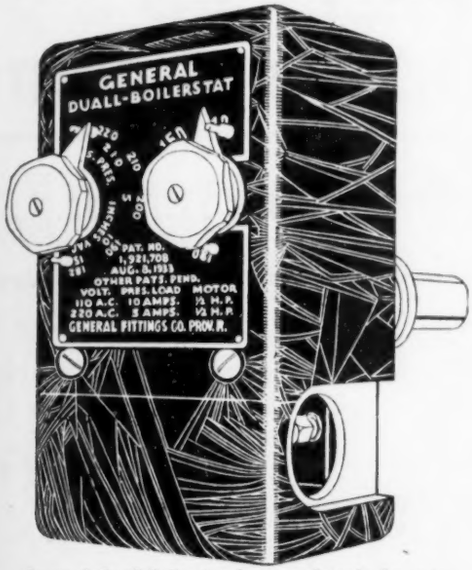

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- **Sensitivity** — Operation on .001" movement.

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TYPES: Red Top — Normally closed. Green Top — Normally open. Blue Top — Double throw.

INSTRUMENTS

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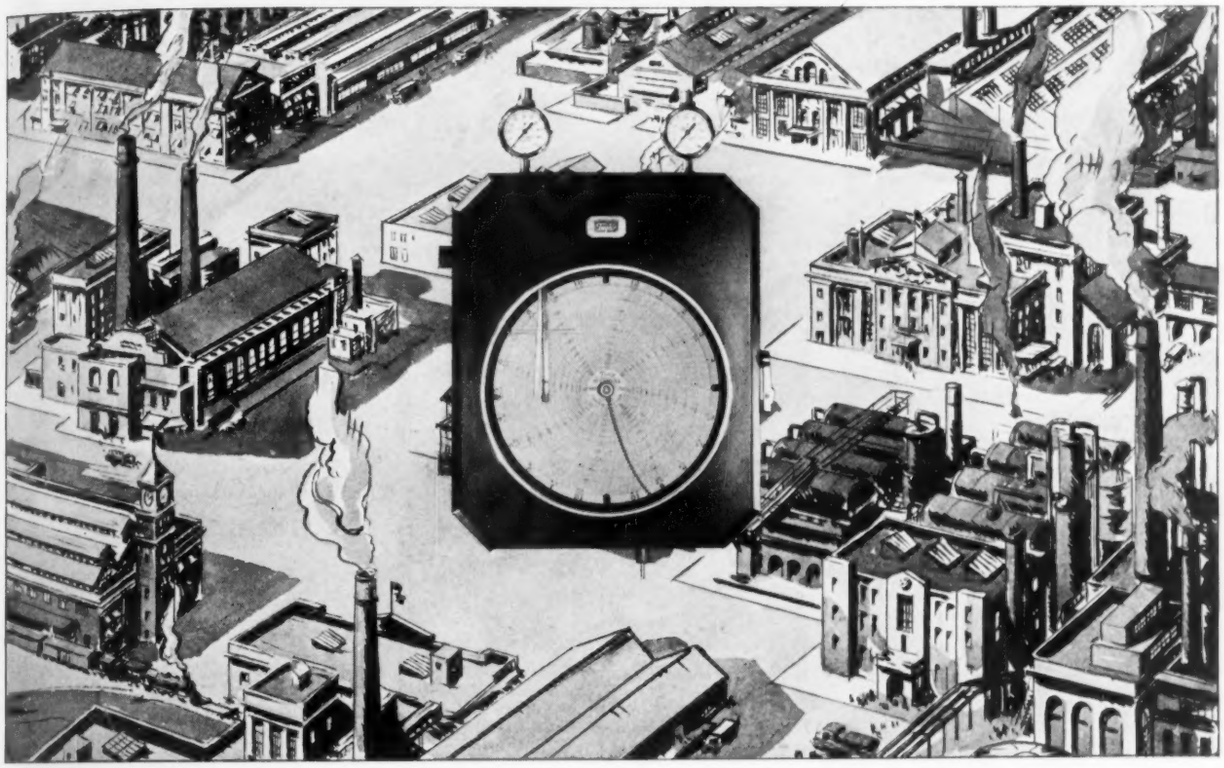
$11,928 SAVED...

BY TEMPERATURE CONTROL



Taylor System again proves its value to industry by cutting operating costs, increasing plant efficiency and maintaining product uniformity

SAVINGS to one plant in a year's time are nearly triple the cost of equipment and installation of the control system.

Here are figures that speak louder than theories or any words in favor of *engineered temperature control.*

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Electrical Engineer
Jersey City, N. J.
Aug. 18, 1934

"Kindly enter the 13 names on the attached list to your subscription list for one year. A check for $13.00 to cover this is enclosed." WM. E. ENGELHARD
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Aug. 6, 1934

". . . May I at this time compliment your magazine on the outstanding character of editorials and descriptions of new instrument developments. The text is precise and to the point. **Instruments** is in a class by itself; a very valuable publication." S. SPECHT
Chief Engineer
Ferrous Magnetic Corp.
New York, Aug. 22, 1934

EDITORIAL COMMENT

In This Issue

Two articles on recent work in magnetic measurements: Woodward and Furth describe their "apotheosis" of the well-known Epstein test; while Dr. Specht announces a quick but trustworthy tell-tale for abnormal steel.

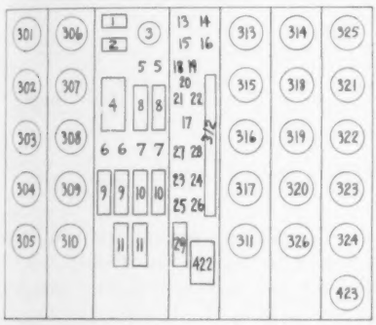
"All sciences are interdependent." Dr. Bullowa, the oxygen-tent specialist, reports findings of interest to industrial engineers.

So rapid are advances in measurements of unbalanced electrical loads that one almost needs a high-speed movie camera. We don't know whether Perry Borden owns one, but we *do* know that he is close to that work.

The Front Cover

Again a handsome board "enshrined" in decorative tile. L. E. Manley, Ass't to Pres., Super-Power Co. of Illinois, kindly sends us a complete list and a guide-map:

301. Turbine throttle pressure.
302. First admission pressure.
303. Second admission pressure.
304. Third admission pressure.
305. Thirteenth stage pressure.
306. Steam pressure to Reheater.
307. Steam pressure from Reheater.
308. Twentieth stage pressure.
309. Twenty-fourth stage pressure.
310. Twenty-seventh stage pressure.



1. Wattmeter.
2. Wattmeter.
3. Frequency meter.
4. Signal Box.
5. Position indicator 24" Bypass Reheat valve.
6. Position indicator 24" Reheat valve.
7. Position indicator 26" Reheat valve.
8. Control for 24" Bypass Reheat valve.
9. Control for 24" Reheat valve.
10. Control for 26" Reheat valve.
11. Control for 16" main steam header valve.
12. Call bell.
13. Ammeter for Generator ventilating fan A.
14. Ammeter for Generator ventilating fan B.
15. Ammeter for Generator ventilating fan C.
16. Ammeter for Generator ventilating fan D.
17. Generator air inlet alarm.
18. Circulating pump No. 1.
19. Circulating pump No. 2.
20. Hotwell pump No. 1.
21. Hotwell pump No. 2.
22. Hotwell pump No. 3.
23. Control for Generator Ventilating fan A.
24. Control for Generator Ventilating fan B.
25. Control for Generator Ventilating fan C.
26. Control for Generator Ventilating fan D.
27. Moisture indicator test switch.
28. Moisture indicator alarm cutout.
29. Vacuum breaking valve control.
30. Grillage for Alarm bells.
311. Condenser temperature.
312. Exhaust head vacuum.
313. Gland water supply pressure.
314. Air cooler water pressure.
315. Temp. and press. Steam at Throttle.
316. Temp. and press. Steam to Reheater.
317. Temp. and press. Steam from Reheater.
318. Generator air temperature.
319. Oil temp. from cooler.
320. Oil temp. from H.P. and L.P. thrust bearings.
321. Condensate temp. from Air ejectors.
322. Condensate temp. from 1 and 2 heaters.
323. Condensate temp. from Evaporator Condenser and heater No. 3.
324. Condensate temp. from heater No. 4.
325. Steam pressure to air ejector.
326. Water temp. from oil cooler.
422. Condenser leakage meter.
423. Pressure—reclaimed ground water.

"Worth Retelling"—??

FROM time to time kind friends suggest that we reprint old but still-timely editorials. A better service, maybe, would be to point out when and wherein we were wrong or stupid. Anyway, our resistance being low as we go to press, we'll clip the passages that bear the greatest number of "by request" check-marks:

SCRIBBLING and speechifying statesmen, seers and "spokesmen" have overlooked this bright spot [continued instrumentation of plants] on the generally dark industrial map. . . Things don't just happen. Two groups of men deserve the credit—the buyers and the sellers. . . Instrument sales engineers who for **years** had painstakingly surveyed plants with the courteous assistance of the plant engineers. . . Among these thousands not one made speeches on how to restore industrial prosperity: too busy **showing** one way. (April '31)

Throwing out trained engineers, research workers and laboratory technicians . . . decisions inspired by fear or greed are not only unwise but inhuman. (June '31)

Stay in the Pink to Keep Out of the Red. Fierce competition will continue for many months in some industries, for years in others. . . Not a sprint but a long marathon. . . Instruments contribute to a plant's endurance [like] general precautions continuously taken by an athlete to keep in the pink. . . Periodical inspections of every piece of equipment. (Oct. '32)

First, do not send good dollars after bad pennies by repairing obsolete instruments instead of replacing them by improved models at a cost in some cases lower. Bear in mind that the appraisal value is seldom increased in proportion to the repair cost . . . where such an instrument or control system can conveniently be removed it should preferably be sent to the original manufacturer. . . "Bootleg parts" may impair the accuracy or value. . . A large investment is represented by a reputable repair shop or an instrument company's "direct factory branch.". . Beware of "bootleg charts." (Nov. '32)

Woe henceforth to businesses that fail to go after that vitally necessary food known as **profits!** . . . American industries are not a herd of bisons to be saved from starvation by a benevolent government. Close your ears to wish-inspired rumors of paternalistic panaceas, for the Socialistic Santa Claus is a myth. Open your eyes to grim reality. Adapt your plant to changing conditions. Modernize! . . . Modernization consists essentially of controlling all variables. (Dec. '32)

Personal Preparedness. Next to the statistical fact of demotions for the average, the significant fact that promotions came to . . . alert men who keep up their market value by keeping up their acquaintance with new developments. (Mar. '33)

The millenium has not arrived. People still go in business for profits. . . It usually takes more heads than one to determine the One Best Way. . . Get together! Show your cards! Ask and answer all relevant questions! Above all, don't nurse grudges. . . We are all colleagues in one esteemed profession . . . that strives to make better things for mankind and to eliminate human drudgery. (June '33)

Trouble with some leaders is that they control by brute force, disregarding human nature factors. These are not exactly **measurable** but their positive or negative intensities are nonetheless **determinable**. . . Tyrannies resemble faulty-control applications where excessive power consumption is required to prevent the process running wild. (July '33)

Brain Trust members have laid emphasis on the **creation of future employment**. Of all creators of future employment research workers are the most effective. What in the name of common sense is the idea of throwing out of work hundreds of this nation's most useful work creators [at Bureau of Standards, etc.] as part of a program of putting idle men to work? . . . A stupid error. . . It seems that there is a "blind spot." (Aug. '33)

The present is a time of stress and taboos abound. It is heresy to declare that proprietors are entitled to more than 4% and that technicians are entitled to high salaries or large fees. . . A State Religion with a credo including "Allah is NIRA and NRA is his prophet. Thy wages shall be increased but thy employer shall not pass on the cost to them that purchase in the marketplace. Thou shalt get free electricity, free gas, free rides. . . Thou shalt not discuss with thy neighbor the possibilities of automatic control. . . Engineers, inventors and managers are imps of Satan. . . " (Sept. '33)

On all these subjects we still feel the same way. What do YOU think?

Core Loss Testing of Magnetic Materials

By W. R. WOODWARD* and E. L. FURTH*

WHEN one considers that magnetic materials constitute approximately 30% of the weight of most electrical apparatus, one appreciates the importance of data on these materials. Permeability, core loss, and exciting current values are of chief interest, and it is necessary to be continually making these tests in order to

(a) Obtain characteristics and application data for the design engineer,

(b) Check the quality of purchased materials, and

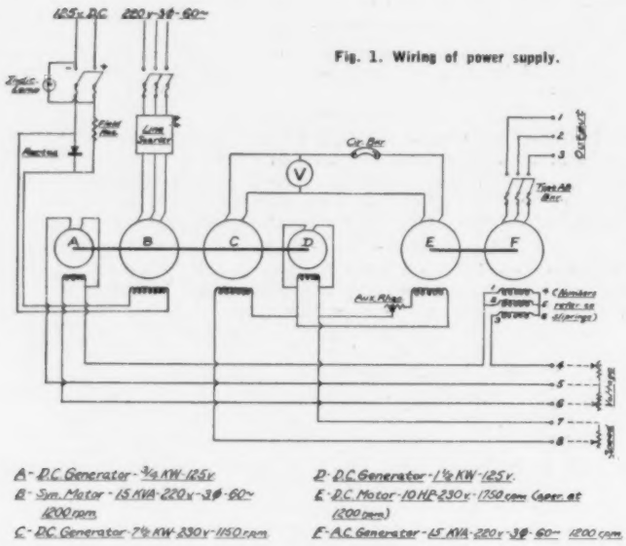

125 v. D.C.
220 v. 3Φ. 60~
Cir. Bkr.
Aux. Relay
A
B
C
D
E
F
A - D.C. Generator - 3/4 KW. 125 v.
B - Sym. Motor - 15 KVA. 220 v. - 3Φ. 60~ 1200 rpm.
C - D.C. Generator - 7 1/2 KW. 230 v. - 1150 r.p.m.
D - D.C. Generator - 1 1/2 KW. - 125 v.
E - D.C. Motor - 10 H.P. 230 v. - 1750 r.p.m. (spec. at 1200 r.p.m.)
F - A.C. Generator - 15 KVA. 220 v. - 3Φ. 60~ 1200 r.p.m.

Fig. 1. Wiring of power supply.

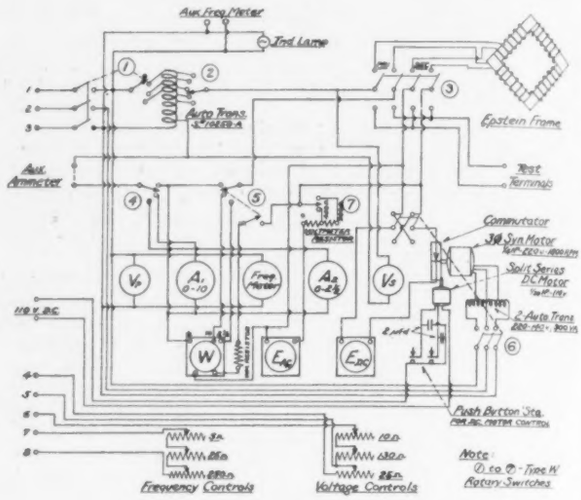


Fig. 2. Wiring diagram of test table.

(c) Obtain data looking towards improvement of materials.

The testing equipment described herein is designed to measure core loss and exciting currents of magnetic materials with accuracy, speed, and unusual convenience. Use is made of the standard Epstein frame for testing small samples under known and controlled conditions. This method, which has been standardized by the American Society for Testing Materials[1], is equivalent to a no-load test on a transformer—the Epstein frame constituting the primary and secondary windings of the transformer, and the sample under test the removable core. The test differs from the standard transformer test only in that potential measurements are taken on the secondary side, thus eliminating the effects of the *IR* drop in the primary. Essentially the frame consists of four coils, each having two separate 150-turn windings, with the four coils assembled to form a hollow square, and the several primary and secondary windings connected in series. The sample, in the form of laminations 3 cm. wide × 50 cm. long (1-3/16" × 19-11/16"), in four bundles of equal weight, is inserted in the frame with butt joints to form a magnetic circuit 200 cm. long. The equipment is designed to take samples weighing up to 10 kilograms (22 lbs.) although 5 kilogram samples (11 lbs.) are more often used in the laboratory.

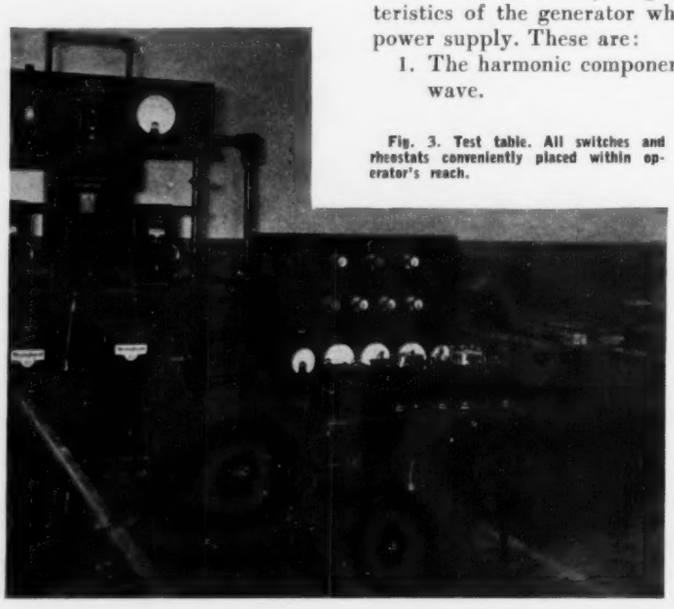


Fig. 3. Test table. All switches and rheostats conveniently placed within operator's reach.

Two factors which affect the accuracy of the Epstein core loss test are very largely a function of the characteristics of the generator which serves as the source of power supply. These are:

1. The harmonic components in the generated voltage wave.
2. The reactance of the generator.

Any harmonics present in the generated voltage are undesirable because they will change the form factor (ratio of r.m.s. value to average value) of the voltage induced in the secondary of the Epstein test frame. In general, the eddy current loss in the laminations is proportional to the root mean square (r.m.s.) value while the hysteresis loss is proportional to the average value of the

*M. & P. Engineering, East Pittsburgh Westinghouse Electric & Mfg. Company.

[1]Spec. A-34-28; 1930 ASTM Standards.

voltage. Any appreciable departure from a pure sine wave will therefore either raise or lower the loss of the iron sample, depending on the distortion of the wave and the ratio of hysteresis to eddy current loss in the sample.

High reactance or resistance in the supply generator or anywhere in the supply circuit will also be a source of harmonic voltages. Even when a pure sine wave voltage is applied to the circuit, the exciting current of the iron cannot be a sine wave but will be badly distorted. G. H. Cole[2] has shown that at a density of 14 kilogausses the exciting current may have about 40% 3rd, and more than 12% 5th harmonic. This current must flow through all the impedances in the circuit, and the voltage drop in these impedances will have the same wave form as the exciting current itself. When these drops (if appreciable) are subtracted from the assumed pure sine wave of the generator, the result cannot be a pure sine wave.

Reactance is more serious than resistance because it increases directly with frequency and thus exaggerates the effects of the harmonic components.

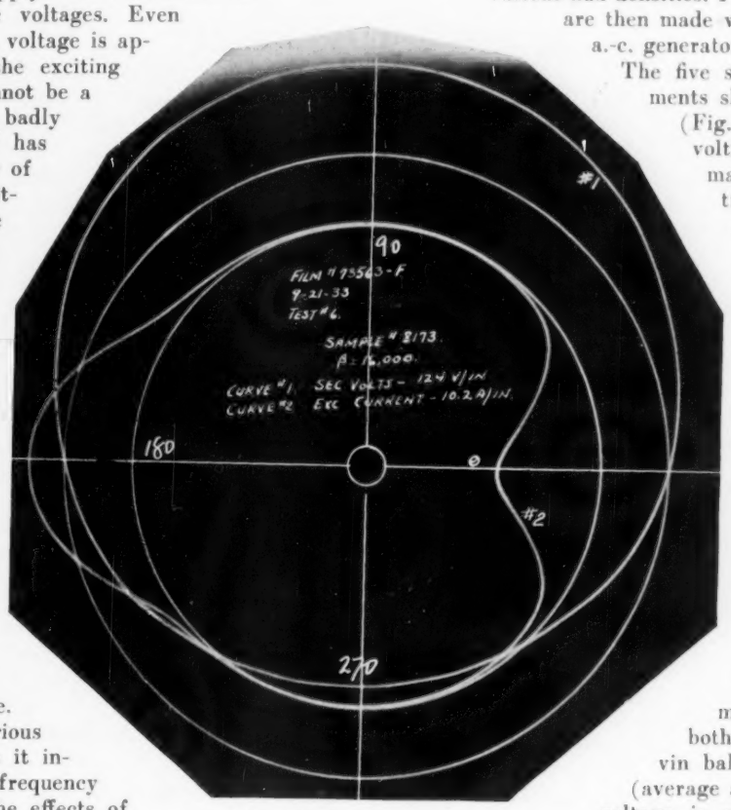


Fig. 4. Circular oscillogram of secondary voltage and exciting current at B = 16000.

It is important, therefore, that the generator not only have good no-load wave form but be of sufficient capacity to have low resistance and low reactance; and it is equally important that the total circuit impedance be kept as low as practicable. A single-phase line-to-line reactance at 60 cycles of 0.3 ohms or less is desirable for the generator, while reactance of the meter windings should not exceed 0.05 ohms.

The source of voltage supply for the test equipment is a specially built 25-kva., 3-phase, 60-cycle a.-c. generator of low reactance, having a substantially pure sine wave voltage at no load. Oscillogram analysis shows all harmonics other than the fundamental to be less than one quarter of one percent of the r.m.s. value. A variable frequency range of 25 to 90 cycles is obtained by driving the generator with a d.-c. motor (unit *E*; Fig. 1). A steady source of d.-c. power is furnished by a second motor generator set, consisting of a d.-c. generator and two exciters, driven by a synchronous motor operated on Central Station power (units *A*, *B*, *C* and *D*; Fig. 1). One exciter is operated at variable voltage to supply the field of the a.-c. generator (unit *F*; Fig. 1), while the second supplies the fields of the d.-c. generator and the d.-c. motor, the latter being kept at a constant value. Variations in speed (and output frequency) are obtained by controlling the voltage applied to the armature circuit of the d.-c. motor. All control rheostats are mounted on the test table.

[2]G. H. Cole, Magnetic Properties of Silicon Steel in a Large Transformer. *Electric Journal*, January 1924, pages 17-24.

Fig. 2 shows the complete circuit of the test table. Since best performance is obtained when the a.-c. generator is operated at rated voltage, a properly tapped auto transformer is used to select the approximate voltage required for testing samples of different weights at various flux densities. Final voltage adjustments are then made with the rheostats in the a.-c. generator field.

The five switchboard type instruments shown in the photograph (Fig. 3) comprise two small voltmeters to indicate primary and secondary auto transformer voltages, two ammeters to measure exciting currents (two being provided to cover the desired current range) and a resonant type frequency meter covering a range of 58 to 62 cycles for 60-cycle testing. Provision is made by means of links for inserting additional ammeters and frequency meters when required. On the table are three portable instruments—An a.-c. (r.m.s.) voltmeter and a wattmeter, both of the precision (Kelvin balance) type, and a d.c. (average a.c.) voltmeter. Average voltage is measured by rectifying the a.-c. wave with a synchronous commutator and reading the resultant half wave on the d.-c. meter. The commutator is driven by a ¼ hp. self excited synchonous motor, and the contact making brush is rotated to obtain commutation at the right point on the voltage wave by a 1/20 hp. split series motor, controlled from a double push button station conveniently placed under the projecting part of the table.

The complete rectifier, cradled on springs to prevent transmission of vibrations, together with the auto transformer, rheostats, and instrument resistors, is mounted at the rear of the test table. Rotary switches of the instrument type, for controlling all meters and circuits, are mounted on the panel so that the entire outfit, with the exception of the Epstein frame itself, is self-contained.

Since core loss, as previously stated, is proportional to the r.m.s. value of the a.-c. voltage while exciting currents as a function of the hysteresis loss are more nearly proportional to the average value of the a.-c. voltage, measurements of the latter are usually made by setting the d.-c. voltmeter to the calculated equivalent sine wave value. For core loss tests, the d.-c. instrument is disconnected and voltage adjustments are made according to the r.m.s. instrument.

In calculating the losses, corrections are made for errors due to phase angle relations in the wattmeter circuit, these being caused by the inductance of the potential circuit and by eddy current losses in the wattmeter frame. While these corrections are relatively small at low inductions, at the higher inductions they become

(Continued on Page 181)

Pressure Error in Gas Analysis by the Thermal Conductivity Method*

By JESSE G. M. BULLOWA**

THE thermal conductivity recorder for the measurement of oxygen and carbon dioxide concentration[1] has been advantageously used by us in connection with our oxygen room and tents (see Fig. 1) for checking the concentration and studying the trends of oxygen and carbon dioxide. This instrument, made by Chas. Engelhard, Inc., employs a Wheatstone bridge with a double by-pass CO_2 cell and a single by-pass O_2 cell, as shown in Fig. 2. The gases are analyzed by their respective power to conduct heat away from a platinum wire embedded in quartz and supplied with a constant current. The gas sample for analysis is introduced by means of a suction pump attached to the apparatus, producing a pressure slightly lower than atmospheric in the analyzing cells. The recorder may be calibrated for use with gas introduced directly from a high-pressure cylinder, with or without the use of the suction pump. Pressure smaller or greater than atmospheric, depending upon the rate of flow of the gas, may thus be produced.

Since the instrument is used for analyzing samples of gas from various sources—room air, conditioning units and chambers, etc.—under differing pressures, the pressure in the cells may not be the same as that at which calibration was made. Even with the same suction pump, occlusion of the ducts may change the rate of suction. The scrubbers, especially the calcium chloride tubes, may vary in resistance from time to time.

On this account, the following observation of an anomaly in recording under two different pressures led us to investigate the effect of changes in pressure on the recording.

An attempt was being made to study directly the seepage of room air into a Bullowa (heat interchanger type) oxygen tent. Oxygen was fed directly into the canopy with a small vent inserted in the duct on the suction side of the blower. A sample of gas was first taken from the suction duct at the outlet from the canopy and then compared with a sample taken from the pressure duct of the unit (see Fig. 1). The recorder indicated a higher concentration of O_2 in the sample taken after the circulating atmosphere was diluted with air sucked through the planned opening on the suction side of the blower. Because of the conditions of the experiment, the oxygen content was actually greater on the suction side. Chemical analyses as indicated in Table I, gave results opposite to those shown by the recorder chart, Fig. 3. The pressures involved are also given.

These paradoxical results led us to study the effect of pressure directly by running mixtures of O_2 and CO_2 from high-pressure (220 cu. ft.) cylinders into the recorder under different negative and positive pressures. The pressure in the system was varied by changing the rate of escape of gas from the cylinder. Pressures were measured by means of a U-tube water manometer connected to the pathway of the gas before it entered the

THOUSANDS of gas analysis recorders in daily use employ thermal conductivity cells. These instruments fill important jobs in various industries. As in all other branches of measurement practice, there are sources of error outside of the instrument and cells. The pressure error is one of the trickiest. It hasn't yet been licked, but Dr. Bullowa and his three assistants have made a distinct contribution toward the definite solution of this problem. They describe anomalies in recording O_2 and CO_2, report experiments with different pressures and stress the need of using pressure-measuring instruments in conjunction with all gas analyzers employing the conductivity principle.

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**Clinical Professor of Medicine, University and Bellevue Hospital Medical College, New York University; Visiting Physician, Harlem Hospital, New York.

[1]Bullowa & Lubin. A Quasi-Continuous Recorder for Oxygen and Carbon Dioxide for Clinical Atmosphere Control. *Journal of Clinical Investigation*, Vol. 10, 1931, No. 3, pages 603 to 631.

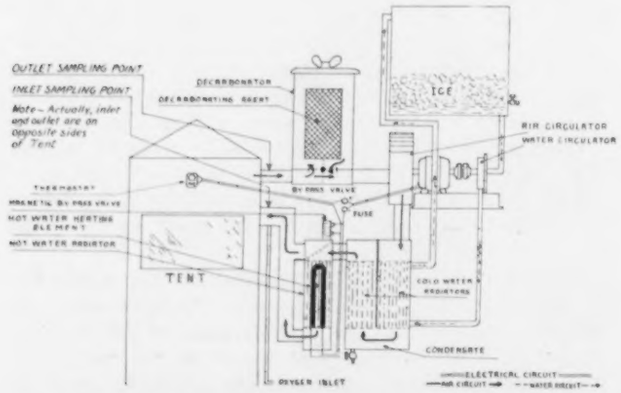


Fig. 1. Schematic diagram of Bullowa Air Conditioner No. 4, showing locations of sampling points.

Table I. Effect of taking sample from suction duct (outlet from canopy) and from pressure duct (inlet to canopy) when oxygen is admitted to canopy and there is a small known seepage of room air on suction side of blower.

ORIGIN OF SAMPLE	PRESSURE	RECORDER		CHEMICAL ANALYSIS	
		CO_2 Double-flow cell	O_2 Sealed Std. cell	CO_2	O_2
	mm. H_2O	%	%	%	%
Outlet duct from canopy (Suction)	— 3	*	59	0	56.8
Inlet duct to canopy (Pressure)	+ 19	.03	62.5	0	54.8

*Negative potential: see Fig. 3 and text of article.

Table II. Effect of variations in pressure on Thermal conductivity record of carbogen (6.8% CO_2, 93% O_2).

Time	Pressure (inches water)	Rate of Flow (bubbles per minute)		Recorder %		Chemical Analysis (Binger) %
		CO_2 cell	O_2 cell	CO_2	O_2	O_2
8:15	+ 2	98	100	6.80	76.5	
9:10	+ 2	100	100	6.83	76.5	86
10:30	— 2	100	100	6.70	24.9	
11:05	— 2	100	100	6.62	29.5	35
12:05	— 2	100	100	6.62	29.5	34

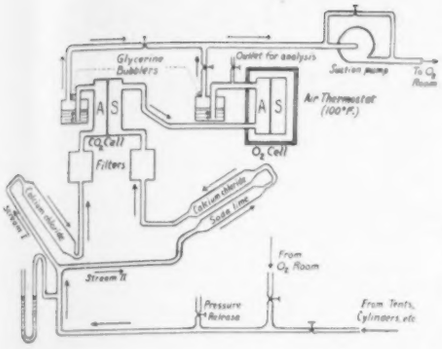


Fig. 2. Flow diagram of the oxygen-carbon dioxide recorder.
AA—Analyzing compartments of cells.
SS—Standard compartments.
CO_2 cell: $O_2+N_2+CO_2$ in A; O_2+N_2 in S
O_2 cell: O_2+N_2 in A; dried normal air in S

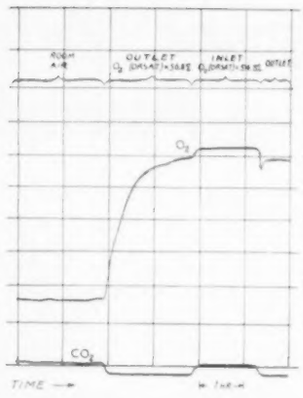


Fig. 3. Thermal conductivity records showing differences in both O_2 and CO_2 between samples taken from outlet (suction) duct and inlet (pressure) duct of an oxygen tent.

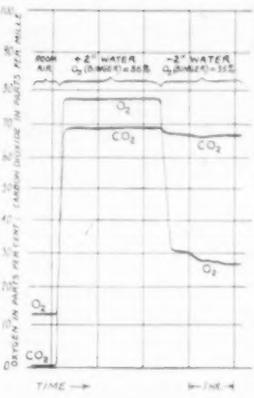


Fig. 4. Thermal conductivity record of carbogen (6.8% CO_2; 93% O_2) under positive and negative pressures. Sensitivity of O_2 cell purposely lowered.

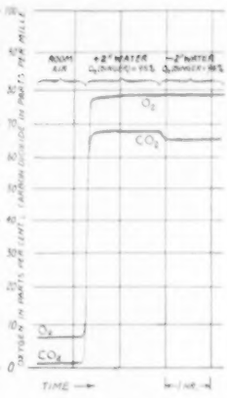


Fig. 5. Test with carbogen as in Fig. 4, after all leaks in oxygen train were eliminated: CO_2 record affected by pressure change.

cells. The water manometer preceded the calcium chloride scrubber. The flow rate through the cells was controlled by maintaining approximately constant (90 to 100 bubbles per minute) the rate of gas bubbling through the glycerine bottles, which are remote from the cells. Within these limits the instrument is not sensitive to changes in flow rate. All rubber connections were made with fresh, cleaned pressure tubing. Whenever possible, brass piping was used, all joints and couplings being sealed with aluminum paint. Occasional analyses with a Binger burette were made at the outlet of the analysis chamber of the oxygen cell (A, Fig. 2) to check the oxygen concentration at that point.

Our first experiments showed marked changes of recording of both carbon dioxide and oxygen, especially the latter, with pressure changes of less than an inch of water. A typical record is shown in Fig. 4 and given in Table II. The gas mixture introduced consisted of 93% oxygen and 6.8% carbon dioxide. With a positive pressure of 2″ water, the recorder read 76.5 for O_2 and 6.8 for CO_2—the sensitivity of the oxygen cell having been lowered so that in the event of a large positive change in the oxygen record, the needle should not go off scale. Changing the pressure to negative (— 2″ water) caused the CO_2 reading to fall somewhat to about 6.6% and the O_2 record to fall markedly to 29.5%. Chemical analysis with the Binger, however, showed that the oxygen concentration had fallen to 34%, indicating a leak in the system.

We then attempted to make the system gas-tight by spraying repeatedly with aluminum paint all possible points of leakage. Subsequent records, such as that given in Table III and Fig. 5, showed changes in only the CO_2 record when the pressure varied from + 2″ to — 2″ of water. The O_2 record remained constant. The decreases in the CO_2 record under negative pressure may be ascribed to minute leaks in the pathway of this gas which is, to a certain extent, independent of the pathway of the oxygen.

Table III. Effect of variations in pressure on thermal conductivity record of carbogen (6.8% CO_2, 93% O_2), after all leaks in oxygen train were eliminated.

Time	Pressure (inches water)	Rate of Flow (bubbles per minute) CO_2 cell	Rate of Flow (bubbles per minute) O_2 cell	Recorder % CO_2	Recorder % O_2	Chemical Analysis (Binger) O_2 %
2:20	+ 2	100	100	6.50	75.0	
3:30	+ 2	100	100	6.80	78.7	95
4:00	— 2	100	100	6.60	78.7	
4.45	— 2	100	100	6.56	78.7	94

It will be noted in Fig. 3 that under negative pressure the CO_2 record is below zero. Daynes[2] cites the variation of the gas in either cell as a possible cause of instability of zero. He notes that "errors caused by pressure changes, being due to convection, are rather more marked with the denser gases."

Our original observation of the anomalous records obtained from the suction and pressure ducts of the oxygen tent may therefore be explained as being due to the presence of leaks in the gas train. Under negative pressure of gas, such leaks result in dilution of the gas with outside air. It is desirable, therefore, to attach a manometer to the instrument to serve as a warning against inward seepage when working under negative pressure.

Although signed by one worker, this article reports investigations (covering more than one year) conducted by Messrs. S. H. Rubin, Manuel Rothstein and Nathan Goldstein (all of the Littauer Pneumonia Research Fund staff) who performed the technical work.

[2]H. A. Daynes, Gas Analysis by Measurement of Thermal Conductivity, Cambridge University Press, 1933, page 131.

Core Loss Testing of Magnetic Materials

(Concluded from Page 179)

quite appreciable. The wattmeter used was specially built for measurements at low power factors.

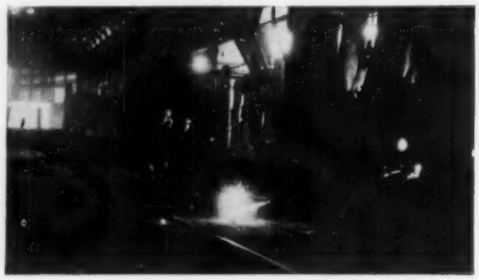
The entire outfit is extremely flexible, easy to operate, and permits testing at high speed. The voltage and frequency, after being adjusted to the proper values, remain sufficiently constant to permit one man to operate the set. All apparatus has been so designed as to keep impedances at a minimum with the result that the wave form as measured on the secondary side of the Epstein circuit is extremely good. With ordinary high silicon steel samples, the form factor at 10 and 14 kilogausses will be 1.11 as closely as can be measured, while at 16 kilogausses it may be as high as 1.13 or 1.14. Fig. 4 shows a circular oscillogram of exciting current and secondary voltage taken at 16 kilogausses, 60 cycles, on a typical 11-lb. sample. The voltage wave form factor as measured was 1.123 and analysis indicated 3.25% 3rd, 2.86% 5th, and 2.14% 7th harmonics. Analysis of the corresponding exciting current wave indicated 81.9% fundamental, 52.2% 3rd, 23.1% 5th, 6.05% 7th, and 1.48% 9th harmonic.

A Thermo-magnetic Method for Rapid Determination of Abnormality in Steel

By SIGFRID SPECHT*

1. INTRODUCTION

NORMAL steel is that from which it is possible to produce properly case-hardened articles; and abnormality is the property (or combination of properties) which prevents a steel of seemingly identical composition and history from taking an acceptable case that will harden satisfactorily on quenching. Usual symptoms of abnormality are "soft spots." Up to 1922, steel mill metallurgists and manufacturers of case-hardened articles believed that all defective case-hardening was due to incorrect practice in the forming, carburizing and hardening operations—a belief founded on the failure of all efforts to discover *before carburizing* any differences between "good" and "bad" carburizing steel of identical analysis: all chemical tests, microscopic examinations and other methods then in vogue gave no indication whereby the men in the forging, rolling, heat treating and fabricating departments could tell whether a certain furnace charge, or ingot, or bloom, or bar, or billet, would or would not carburize properly. "Mysterious failures to obtain a uniformly hard product" were "often reported."[1]



POURING A SMALL TEST INGOT
(Courtesy Midvale Steel Co.)

In 1922 McQuaid and Ehn published[1, 2, 3] their important discovery "that the structure of the case both before and after quenching is greatly affected by the actual condition of *the steel itself as made* . . . Work from good batches hardens properly whereas the other work will not harden" when subjected to identical forming and heat-treating operations.

They discovered that *carburizing brings out differences* in structure between steels that (1) otherwise appeared, by all tests then known, to be alike, and (2) were subjected to the same operations between the ladle or ingot and the carburized sample. They showed that "microscopic examination . . . developed a striking difference between steels that would show soft areas after quenching and those that would be satisfactory," and proposed a standard procedure, involving a definite carburizing treatment followed by a microscopic examination of carburized samples. This test procedure has remained practically unaltered as the only accepted Standard Test for determining whether the steel in a given ingot is normal or abnormal steel. The observer looks for what McQuaid and Ehn described as "a characteristic structure in the hypereutectoid zone . . . formed after carburizing in the steel giving trouble."

Valuable discussions and definitions of "abnormality," with reference to the McQuaid-Ehn Test, have since then been published by Epstein and Rawdon[5, 9], by Gat[6], by Grossman[10] and by Herty, Fitterer and Byrns[11, 12]; but considerable divergences of opinion still prevail among metallurgists when it comes to interpreting these definitions in actual practice. One reason has been the lack of a test whereby a quantitative determination could be made and the result expressed as a number. In other words, all present methods of determining whether a given specimen is "normal" or "abnormal" include visual examinations. Needless to say, the inclusion in any test procedure of even one qualitative factor renders the entire test qualitative and its result an estimate rather than a measurement. The present article announces a new method wherein human judgment is eliminated and whereby determinations are made quantitatively. The new method is to some extent a variant of the Standard Test for Abnormality; but whether it be called a "modified McQuaid-Ehn Test" or something else, its results invariably determine normality or abnormality according to the accepted definitions.

2. REQUIREMENTS

Valuable though it has been to numerous manufacturers, the McQuaid-Ehn procedure is too slow for modern plant conditions, usually taking two days—during which the whole furnace charge must be kept in the form of ingots before a decision can be made as to their subsequent disposition. The first requirement that faced us, therefore, was to develop a method that would save the two days and the costs they represent.

Another objective of the research—closely tied up to the first requirement—was that samples should not have to be procured from an already released heat. The new method had to be applicable to miniature ingots cast while the heat is still in the furnace, or to samples taken from the ladle platform.

There was thus sought the advantage of quickly and accurately passing the information obtained to the furnace operator, allowing time for changes to be made in the furnace charge, or permitting changes to be made in the ladle. In the present state of ferrous metallurgy, to be sure, total conversion (from abnormal to normal) cannot be made, but the data obtained on a quickly-prepared specimen should nevertheless result in considerable saving of time and operating expense, as compared to the present method of test.

These data should not consist of a description of the microstructure: the ideal test result should be expressible as a number—the degree of abnormality—correctly signifying the hardening property.

Above all, the human equation had to be eliminated: an obvious disadvantage of the present standard method lies in the fact that this particular test (including certain set constants of heat-treatment and final microscopic analysis as to the structure and grain development) depends upon many factors subject to variations due to mode of operation and due to varying diagnostic conception of the microscopic results obtained. These variations

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are carried through from one steel mill to the other as well as between steel mill and consumer.

The object of the search summarized itself, then, into "a fully automatic apparatus which will subject a small sample to a standard and reproducible heat treatment, indicate its degree of abnormality on a numerical scale, and do it quickly."

3. DIRECTION OF DEVELOPMENT

Solution of the problem was sought along the line of a magnetic test, as offering the best chance of developing a *measuring* instrument—one that would give quantitative readings. There were two apparently serious difficulties: (1) magnetic tests on carburized specimens—no matter how indicative—would not do away with the lost-time factor and its attendant costs in plant operation, and (2) various magnetic tests on untreated samples from normal and abnormal ingots before carburizing gave insufficiently conclusive results, the reason (later discovered) being that the samples were "cold."

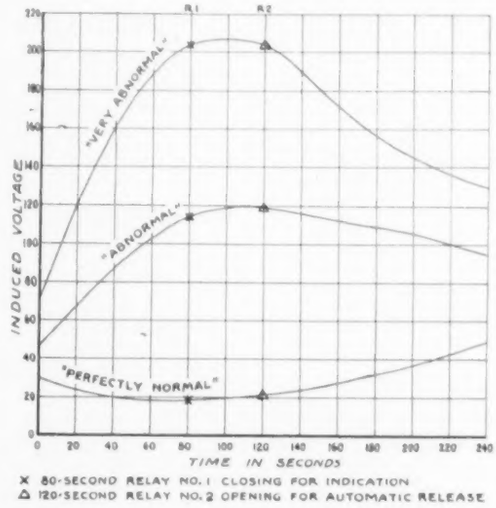


Fig. 1

An extensive research covering more than two years brought out that the definite correlation sought for — between "degree of abnormality" and a magnetic effect readable on the scale of an electrical instrument—manifested itself on heating the specimen to a certain critical temperature inversely proportional to the magnetization; without, however, reaching the critical temperature at which structural changes occur in ferrous alloys.

This naturally suggested the development of a time-saving device in the form of a combination coil for simultaneously magnetizing and heating the sample; it dictated the form that the samples should take: a round bar.

Further research brought out that the most indicative readings were obtained by using an electrical ratio instrument, with a "Standard Sample" in one coil and the test sample in another. Development since then was therefore directed to ascertaining the optimum physical dimensions and electrical constants of a two-coil type of inspection instrument and to determining the optimum heating period. A period of 80 seconds for heating the sample was found to give the most sensitive results. See Fig. 1.

On purely theoretical grounds the objection might be raised that a differential magnetic measurement, read off on a commercial voltmeter, is not a reading of "the microstructure of abnormal steel." But abnormality—as far as the practical worker is concerned—is neither a peculiar microstructure nor a peculiar diffraction spectrum. It is "that property of a steel which affects its suitability for case-hardening," and nothing else. The thermo-magnetic test is a true *measure* of that property—of the degree of abnormality—as is apparent from Fig. 1 which shows the thermo-magnetic test readings of three samples designated by metallurgists, employing the McQuaid-Ehn Test, as (1) "perfectly normal," (2) "abnormal" and (3) "very abnormal." Note that at the end of the 80-sec. heating periods the readings were 18, 112, and 204.

The specificity of the new thermo-magnetic method was moreover checked by numerous McQuaid-Ehn tests made after the degree of abnormality of samples from the same heats had been reported in terms of thermo-magnetic readings. See Figs. 2 and 3.

Numerous experiments were conducted in order to attempt to introduce disturbing factors that would invalidate the readings of the thermo-magnetic instrument as specific criteria of abnormality. It was determined that no factors which might occur in practice could falsify the readings to an appreciable extent. Consequently, the later development work has been directed toward making the two-coil thermo-magnetic type of instrument fully automatic.

4. DESCRIPTION OF EQUIPMENT

The equipment consists essentially of magnetizing coils with their respective secondary or exploring coils wound in opposition. See Fig. 4. The primary or magnetizing coils are excited by 110 volts 25 or 60 cycles.

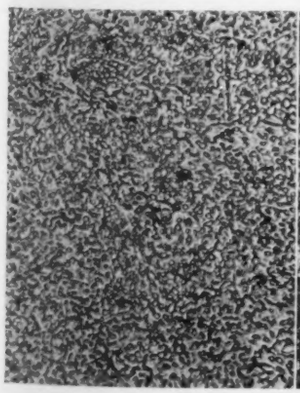
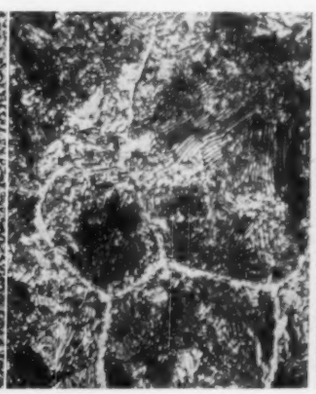


Fig. 2. TEST SAMPLE No. 1. Magnification 400×

Before carburizing. Carbides in spheroidal condition. Thermo-magnetic inspection indicated this sample to be normal.



After carburizing at 1750°F. for 6 hours. Structure indicates normal steel, verifying previous thermo-magnetic inspection.

Fig. 3. TEST SAMPLE No. 2. Magnification 400×

Before carburizing. Mainly pearlitic with few spheroidized carbides. Thermo-magnetic inspection indicated high abnormality.

After carburizing at 1750°F. for 6 hours. Small grain, complete separation of ferrite (at top), verifying previous thermo-magnetic inspection.

This makes it possible to determine whether the magnetic properties of the sample under test are identical with those of the predetermined Standard since, when identical, the two induced voltages will be equal and opposite at every instant, making their resultant voltage equal to zero. When, however, the specimens are unlike magnetically (a departure from the predetermined Standard), the secondary voltages will likewise differ, both in value and in wave shape, and the resultant voltage will increase in value and in distortion from sinusoidal wave shape. A particular form of distortion may be employed to indicate a particular kind of deviation in magnetic characteristics, which may be found by trial to be the most closely correlated to particular physical chemical properties under investigation. Stated differently, certain harmonic frequencies will be the most accurate for indicating certain magnetic deviations since the distortion of a wave form depends upon harmonic frequencies present.

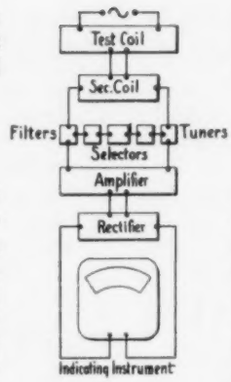


Fig. 4

Certain harmonics may be too small to detect or measure directly by ordinary electrical measuring instruments, in which case the use of a tuned circuit and triode amplifying equipment may be resorted to. This is done in the present equipment.

Automatic timing relays are employed to hold the measuring instrument circuit open until 80 seconds after closing the circuit. Another relay then ends the test after another 40-second interval by releasing the sample and automatically dropping it into a cooling tank. This operation also opens the test circuit.

The scale markings on the indicating instrument (see Fig. 5) indicate the ranges for "normal" and "abnormal" steels respectively. If desired, a second scale may be provided for indicating the grain size of the test sample. Two distinct circuit operations are necessary, one for abnormality (duration of test 80 seconds) and one for determination of grain size, this second operation being practically instantaneous.

The apparatus is simple. An untrained person may operate it. The following is the procedure for its use:

After connecting the apparatus to the 110 volt a.c. line, power switch may be closed, which permits amplifier tubes to heat up. (Time factor for heating tubes approx. 30 seconds.)

The specimen is then placed in test coil (the Standard Sample being a permanent fixture of the apparatus); relay switch is then closed and approximately 80 seconds after closing of the power switch, the relays will automatically throw the indicating instrument into circuit. Approximately 40 seconds later, the test sample will be released, dropping into cooling tank.

Relay switch is then moved to "off" position and allowing for 1 minute of cooling, test on the remainder of specimens may proceed.

After all tests have been completed, Power and Relay Switch should be turned to "off" position, totally disconnecting the apparatus from power supply.

The tubes employed are of standard make and design. They must be changed at the usual intervals. Any decrease in the efficiency of the tubes, or fault in their operation, is immediately recognized and indicated by instruments forming a part of the tube circuit.

The instrument as such will not replace the McQuaid-Ehn test, but will materially help in standardizing the results. The primary field of application, however, will be as a tool for the electric furnace and open hearth and as a research and control instrument in the laboratory of the steel mill and manufacturer alike.

Note on Preparation of Specimens. The Standard Sample (which forms a part of the circuit and apparatus) and the individual test samples (each representing a heat under study) are miniature test ingots forged down to $\frac{3}{8}$" diam. $\times$ $9\frac{1}{2}$" long; surface cleaned of loose scale; straightened if necessary for easy insertion in the coils. Defects on surface or interior do not impair accuracy of determinations.

5. ACKNOWLEDGEMENTS

J. K. Liebing, research engineer on the staff of the Ferrous Magnetic Corp., assisted in the development of both the method and apparatus.

The writer desires to thank the Firth-Sterling Steel Co. for preparing the samples shown in Figs. 2 and 3.

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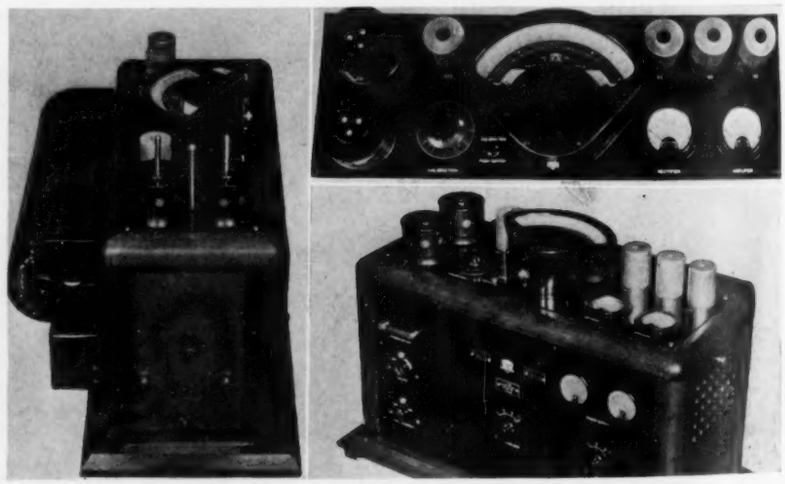

Fig. 5. A practical embodiment of the new thermo-magnetic method: entire apparatus in one transportable assembly. LEFT—End view showing Standard Sample and test sample inserted in their respective coils. UPPER RIGHT—Top view, showing direct-reading Abnormality Indicater. LOWER RIGHT—General view.

Measurements on Unbalanced Electrical Systems*

By PERRY A. BORDEN† and M. F. BEHAR**

1. Unbalanced Loads—General Considerations

(a) Principal Causes of "Unbalance"

In an electrical circuit consisting of a single pair of conductors it is apparent that the current values in the two wires are equal to each other, and that the load is essentially "balanced." In a circuit consisting of more than two conductors, however, it usually is possible for the currents in respective conductors to differ by a considerable amount, giving rise to the condition known as "unbalanced load." While it is desirable in polyphase distribution that the load be maintained as nearly as possible balanced, yet there are certain unavoidable causes which tend to detract from this ideal condition: A single-phase load may be taken from any phase of a three-phase system, and the current represented in that load will flow in but two wires of the circuit. Two single-phase load components may be taken off two phases of a three-phase system, in which case the currents represented by the individual components will flow in two conductors of the system, while the remaining wire will carry their resultant. Moreover, it will readily be seen that a load made up of three single-phase components having equal watt values or equal current values but different power factors will result in a condition of current unbalance in the line.

In most polyphase systems the several voltages, as generated and supplied, are substantially balanced in value; but it is evident that unbalanced currents flowing through considerable impedances will be responsible for unbalanced voltage conditions at the receiving end. Unbalanced voltages, in turn, applied to certain types of apparatus, such as induction motors, tend to produce an exaggerated unbalance of the current values, so that a slight initial voltage unbalance is likely to cause disproportionately unbalanced currents to flow in the system.

(b) Significance and Interpretation of Measurements

In problems of measurement as applied to polyphase systems, it is important that due consideration be given to such conditions of unbalance as may exist. It already has been pointed out that certain connections of instruments for measurement of power, power factor, reactive power, etc., apply only to those circuits wherein a balanced value of currents is assured, and that special arrangements have to be made for conditions of unbalance. The situation is somewhat complicated by the fact that while the definition and basic concept of watts as a measure of power holds good for any condition of unbalance, the definitions of *power factor*, and of those elements which must be taken along with power factor in order fully to identify load conditions in an unbalanced circuit, are more or less indeterminate and open to conjecture.

At a time when the determination of *power factor* as an end to be attained was considered as of great importance, and with a view to eliminating controversy as to its true signifiance, a joint committee of the A.I.E.E. and the N.E.L.A.‡ submitted for consideration two definitions of power factor on polyphase circuits, as follows:[1]

Definition 1: Power factor in a polyphase circuit is the ratio of the total watts to the arithmetical sum of the volt-amperes in the several phases, each measured to a non-inductive neutral point.

Definition 2: Power factor in a polyphase circuit is the ratio of the total watts to the vector sum of the volt-amperes in the several phases.

‡Now called the Edison Institute.

[1]*Transactions A.I.E.E.*, Vol. 39 (1920), page 1450.

*Ninth chapter (XXXVII) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Béhar's *Manual of Instrumentation*. See editorial announcement of this series on page A7 of November 1933 *Instruments*. A complete chapter of this new handbook will be published in each issue of *Instruments* throughout 1934 and 1935. Each chapter is subjected to a final revision, and then set in type, shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright. To be issued in book form on or about Jan. 1, 1936.

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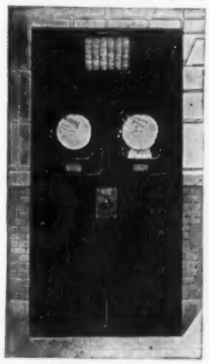

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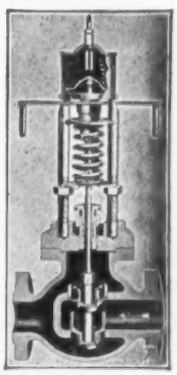

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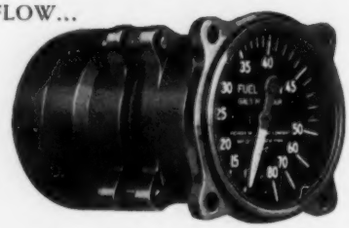

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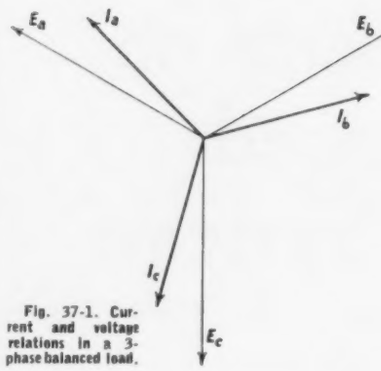

Fig. 37-1. Current and voltage relations in a 3-phase balanced load.

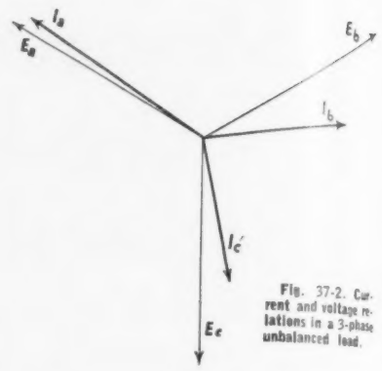

Fig. 37-2. Current and voltage relations in a 3-phase unbalanced load.

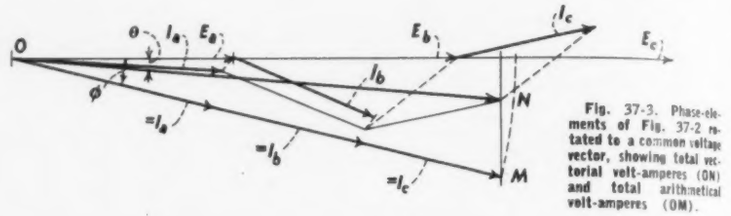

Fig. 37-3. Phase-elements of Fig. 37-2 rotated to a common voltage vector, showing total vectorial volt-amperes (ON) and total arithmetical volt-amperes (OM).

These two definitions differ in but one significant word, one calling for consideration of the total volt-amperes in the system as the *arithmetical*, and the other as the *vectorial*, sum of the volt-amperes in the several phases. Under conditions of balanced load these two concepts are considered to be identical, and both definitions apply equally well; but with unbalanced currents the arithmetical and vectorial sums of the volt-ampere magnitudes are not necessarily equal; and upon this fact much of the controversy has hinged.

A growing realization of the important part played by distortion of the wave form—of either current or voltage or of both—has led to attempts to develop a factor which would take cognizance of this condition in the determination of power flow. Efforts to obtain a conception of a measurable magnitude which would at one time recognize phase displacement, load unbalance and wave-form distortion have thus involved the situation and made electrical engineers reluctant to adopt either of the manifestly inadequate definitions available for power factor. The economic and philosophical aspects of this situation have been fully discussed by the A.I.E.E.[2], and while it appears that there will evolve a more modern and consistent method of treating the whole subject of power flow, it has not been made apparent that the time is yet ripe to abandon the trigonometrical definitions submitted in 1920. It will be well to remember, however, that in subsequent paragraphs of this chapter the term "power factor" is not clothed with the specific meaning it has heretofore borne, and that its use as a matter of convenience implies a broader (and as yet nameless) term which, however inadmissible as a factor in the higher mathematics, has proved of great practical value in actual electrical computations.

Of the two definitions, the second (usually credited to an Italian authority[3] but apparently based on a concept first publicly proposed by Burt before the A.I.E.E.[4]) seems to have found favor in recent years; and most devices and methods for determining power factor or other magnitudes associated with out-of-phase conditions have been based on the idea of the total volt-amperes in the system being represented by the *vectorial* sum of the individual volt-ampere components.

In Fig. 37-1, a vector diagram illustrating conditions attending a three-phase balanced load, it will be seen that the angles between the currents and their respective associated voltages are equal to one another, so that a figure representing the power factor of any one of these can be taken as representative of the whole load of the system. With an unbalanced load, such, for instance, as that shown in Fig. 37-2, it is apparent that the angles of the several currents relative to their respective voltages are not identical, and that a measurement performed on one of the currents relative to its voltage would not necessarily have any significance as a representation of the power factor of the load. This will be clearer on reference to the geometrical treatment, Fig. 37-3: Here the three voltages to neutral E_a, E_b and E_c, are considered as having been rotated into the same line E, and added; the associated currents being turned through

[2]Symposium. *Transactions A.I.E.E.*, Vol 52 (1933), pages 744 to 801.
[3]Campos. *Trans. Assoc. Elettra Ital.*, Vol. 13 (1909), page 197.
[4]Austin Burt. *Transactions A.I.E.E.*, Vol. 27, Part 1 (1908), page 801.

corresponding angles and vectorially combined, as I_a, I_b and I_c, their resultant being represented by the vector ON. Now it will be seen that no single one of these currents can be taken as representative of the whole load; for, if so, three distinct values of power factor could be obtained, according to the current which was selected for measurement.

For the purposes of the second definition, the resultant ON of the three currents may be considered as representing their combined equivalent, and with this construction the angle θ is looked upon as the equivalent phase angle of the system. The sum of the projections of the currents (or the projection of their resultant) on the voltage vector then represents the true active volt-amperes (watts) of the system, and the sum of their projections on the quadrature voltage vector the reactive volt-amperes, or vars.*

According to the first definition the equivalent volt-amperes are taken as the arithmetical, instead of the vectorial, sum of the several currents. Thus, while the active volt-amperes or power would be the same as above, the equivalent current in the system would be represented by the vector OM, equal to the actual sum of the three currents, this vector intersecting the perpendicular to the voltage vector so as to make with the voltage vector an angle ϕ, greater than the angle θ. Thus, on an unbalanced load, the power factor, according to the first definition, would never have a higher value, and generally would have a lower value, than with the second definition. Before making use of either of these definitions the reader is reminded that they have a logical significance only with a balanced sine-wave voltage and a sinusoidal (though not necessarily balanced) current. These conditions, however, characterize a large proportion of the electrical loads met with in everyday practice.

2. Power Factor Indicators for Unbalanced Loads

A simple three-phase power factor indicator for unbalanced loads is shown diagrammatically in Fig. 37-4. Structurally this instrument is similar to the single-current instruments described in Chapter XXXV on Determination of Phase Angle (see Fig. 35-3) but it has three potential coils and three current coils, the three windings of each system being spaced 120 degrees apart. Each of the stationary coils carries one of the three line currents; and to each of the

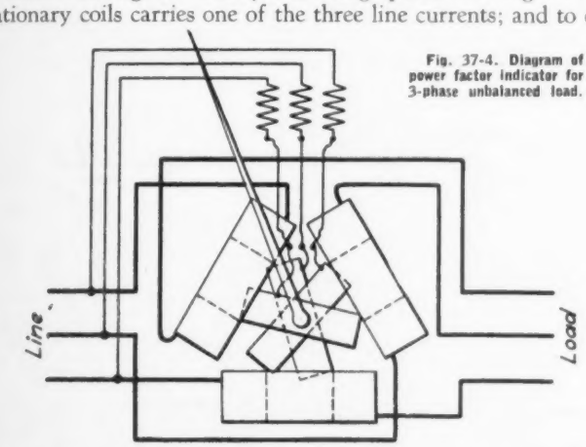

Fig. 37-4. Diagram of power factor indicator for 3-phase unbalanced load.

fine wire coils of the centrally located moving element is applied one of the phase voltages through a suitable series resistor, connection to these coils being made by fine torsionless ligaments allowing free deflection through a large angle without appreciable mechanical control. This type of instrument, connected to a circuit carrying an unbalanced load, provides an indication according to the second definition of power factor, and on a balanced load its readings agree with those of the single-current-coil types. Though relatively little known in this country, it enjoys a wide application in European practice. Fig. 37-5 shows a power factor indicator of this type (built by Nalder) used by one of the authors for many years with gratifying results.

An interesting refinement of this principle (also made by Nalder) was introduced by Dr. Gifford[6] about 1915. In it the currents in the moving element are derived from light fine wire coils concentrically mounted on the moving element and forming the secondary windings of small transformers whose magnetic circuits and primary windings are stationary, the iron of each having an air gap in which moves the disc carrying the secondary coil. With this arrangement, the moving element has no mechanical restraint and may rotate freely to any posi-

*The name *var* for the unit of reactive power was adopted in 1930 at the Stockholm meeting of the Int'l Electrotech. Com. Its derivation is obvious.

[6]Direct Measurement of Power Factor. R. D. Gifford. *Electrician* (London), April 16, 23 & 30, 1915.

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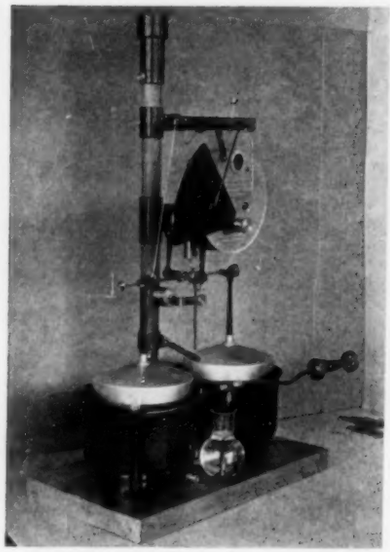

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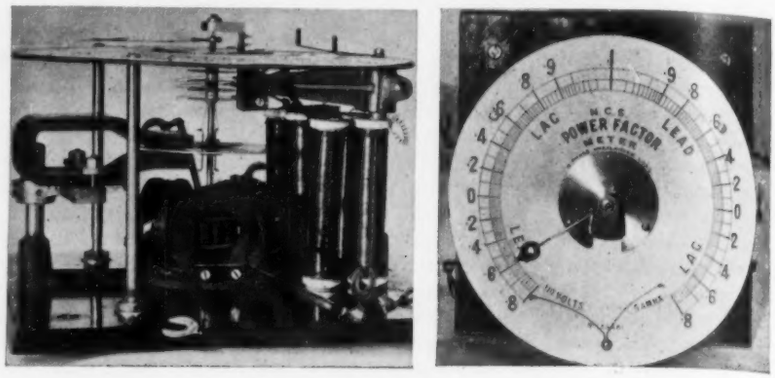

Fig. 37-5. Side and top views of measuring element of Nalder unbalanced load power factor indicator removed from its case.

(Photographs courtesy Hydro-Electric Power Commission of Ontario)

3. Reactive Measurements by Quadrature Voltages

A geometrical analysis shows that the method of determining reactive component by shifting through an angle of 90 electrical degrees the voltage applied to the potential coils of a wattmeter produces on unbalanced loads a result in accord with the Second Definition of power factor. Volt-ampere values computed by extracting the square root of the sum of the squared values of watts and reactive component so determined are equivalent to the vector sum of the volt-ampere values in the several phases of the system. In installations requiring a knowledge of reactive component or power factor, it therefore is common practice to employ this method, as outlined in Chapter XXXV (see Figs. 35-9 and 35-10).

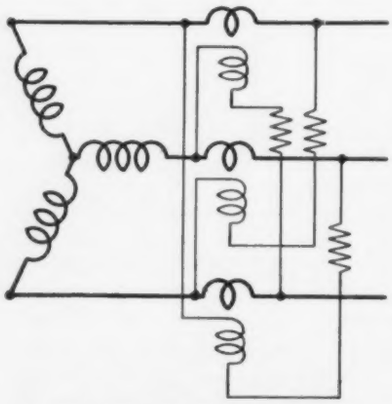

Fig. 37-6. Three-wattmeter method of determining reactive component.

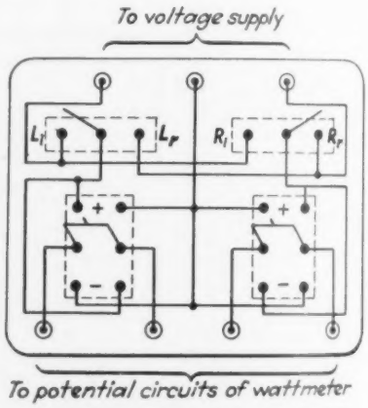

Fig. 37-7. Diagram of test panel for right-hand and left-hand readings.

The three-wattmeter method of measurement lends itself to a rational determination of reactive power by the potential circuit of each element having applied to it the voltage between the two conductors which do not pass through the current coil of that element. See Fig. 37-6. The voltage on each element will then be in quadrature with the voltage normally applied to that element; and, since its magnitude will be $\sqrt{3}$ times that of the normal voltage, the net reading of the wattmeter without further adjustment or compensation will be 1.732 times the reactive power in the circuit.

4. Power Factor from Wattmeter Readings

In general testing work, and on three-phase installations where apparatus for producing quadrature voltages is not available, the following method, first published about 1911 by Baker[6], is of wide application:

[6]H. S. Baker. *Report of Meter Committee.* Canadian Electrical Ass'n, 1911.

(1) Assuming a two-element polyphase wattmeter connected according to the conventional diagram for a three-phase three-wire circuit (Fig. 34-11) and the load reasonably steady, disconnect the "outside" potential leads (leaving series resistors, if any, connected to the instrument) and normal currents flowing in the current windings.

(2) Calling the two elements "left" (L) and "right" (R), make the following four connections in succession:

(a) Apply normal potential to the right-hand element, obtaining reading R_r.

(b) Apply normal potential to the left-hand element, obtaining reading L_l.

(c) Apply left-hand potential to the right-hand element, obtaining reading R_l.

(d) Apply right-hand potential to the left-hand element, obtaining reading L_r.

The first two of the above readings are known as "direct," the last two as "crossed."

It is then found, where θ is the angle whose cosine is considered as the power factor, that

$$\text{Tan } \theta = \frac{(L_l - R_r) - 2(L_r - R_l)}{\sqrt{3}\,(R_r + L_l)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

In making use of this formula the signs of the respective readings must be carefully observed; and where negative readings are obtained either the zero of the instrument must be artificially raised, or a reversal of the applied potential made and a negative sign applied to the reading; or else a positive and a negative reading taken simultaneously and later separated, as explained under similar tests for balanced loads in Chapter XXXV. The system is also applicable to watthour meters; and disk speeds may be compared as in Chapter XXXV.[7]

Since the nomenclature of the readings is arbitrary, all signs may be reversed if more convenient, and the formula made to read:

$$\text{Tan } \theta = \frac{(R_r - L_l) - 2(R_l - L_r)}{\sqrt{3}\,(L_l + R_r)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

In the case of a balanced load it will be found that the crossed readings are equal and opposite in sign, and of a numerical value equal to the difference between the direct readings; or

$$R_r - L_l = R_l = -L_r$$

whence the above formula reduces to

$$\text{Tan } \theta = \sqrt{3}\,\frac{R_r - L_l}{R_r + L_l} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Equation (3) is the equivalent of the formula

$$\text{Tan } \theta = \sqrt{3}\,\frac{W_1 - W_2}{W_1 + W_2},$$

appearing in Chapter XXXV.

In a three-phase four-wire system metered with current transformers connected in delta (Fig. 34-26), the formula becomes:

$$\text{Tan } \theta = \frac{(L_l - R_r) + 2(L_r - R_l)}{\sqrt{3}\,(R_r + L_l)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The only difference between equations (1) and (4) lies in the sign in the numerator of the expression. It may be shown that if the current and voltage in one element of a wattmeter originally connected in the conventional manner both be reversed from their normal arrangement (as by reversing one current transformer and reversing the corresponding voltage transformer), this change, while not affecting the reading of the instrument as a wattmeter, will require for power factor determination that the formula be used as in form (4), rather than as in form (1). In general it may be said that for power factor determination, with a three-phase wattmeter connected so that the voltages in the instrument are 60° apart, the equation having the minus sign should be used, while that with the plus sign applies to connection diagrams giving an angle of 120° between the voltages.

With a value obtained for tan θ, the power factor may be found by reference to trigonometrical tables, or by the use of the second and third columns of Table 35-I in Chapter XXXV.

In Fig. 37-7 is shown the diagram of a simple test panel readily made up in a portable form, and suited for use with any type of three-phase wattmeter for obtaining the direct and crossed readings.

Following is a typical application of the power factor formula:

$R_r = 20 \qquad L_l = 160 \qquad R_l = -160 \qquad L_r = 200$

$$\text{Tan } \theta = \frac{(R_r - L_l) - 2(R_l - L_r)}{\sqrt{3}\,(R_r + L_l)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$= \frac{(20 - 160) - 2(-160 - 200)}{\sqrt{3}\,(20 + 160)}$$

$$= \frac{580}{180\sqrt{3}} = 1.86 = \tan 61.5°$$

$$\text{Power factor} = \cos 61.5° = 0.478 = 47.8\%$$

Another formula also developed by Baker enables the value of volt-amperes in a three-phase three-wire system to be determined in a very simple manner. The method is as follows:

(1) With a polyphase wattmeter connected in the conventional manner (Fig. 34-11) obtain the total reading "S" (in step).

(2) Rotate the potentials 60° in a lagging direction, and obtain a reading "L" (lag). Then:

$$\text{Volt-amperes} = 1.555\,\sqrt{S^2 + L^2 - SL} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

[7] *Instruments*, July 1934, page 141 (Notes under Table 35-1).

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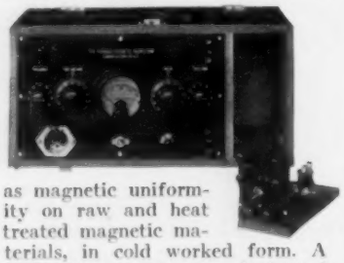

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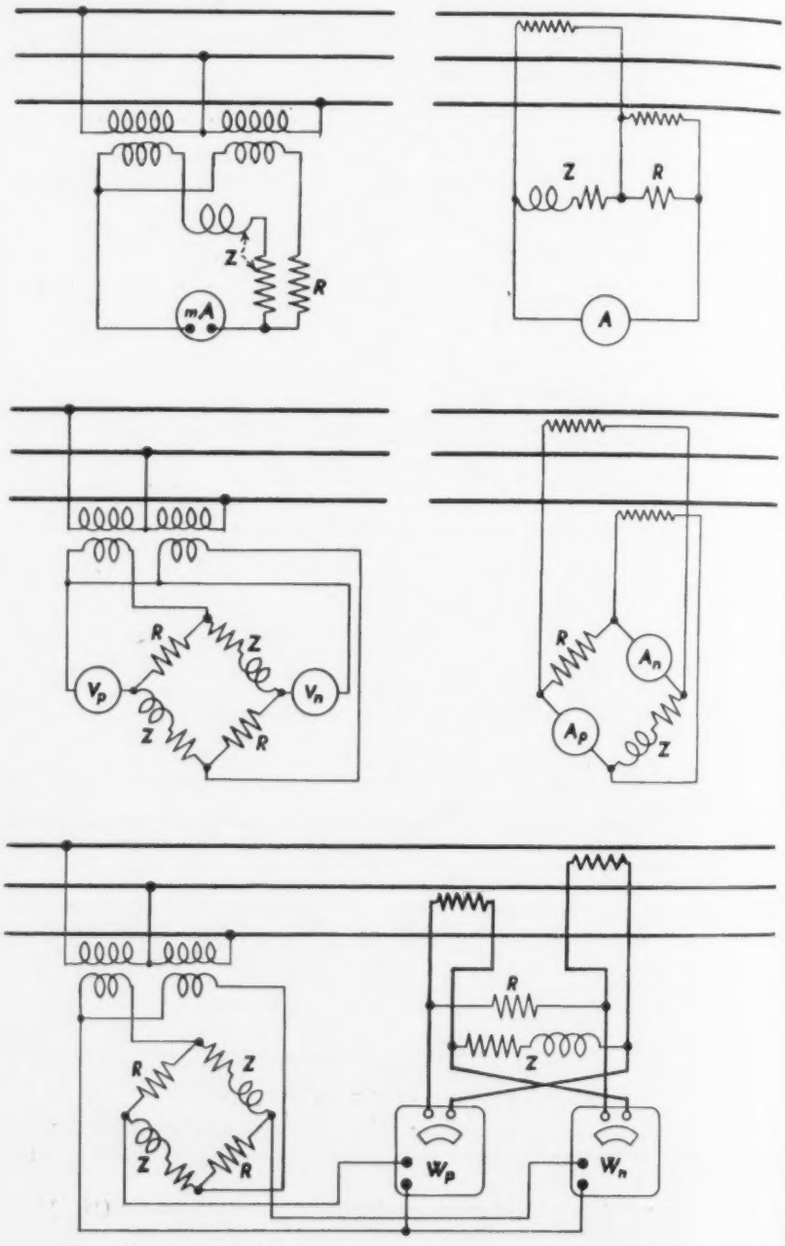
5. Method of Symmetrical Components

Unbalanced load conditions are taken account of in a system of "Symmetrical Components" developed by Fortescue, who shows that unbalanced currents or voltages in a three-phase circuit are capable of resolution into two balanced systems, one of which is of the same phase sequence as the generator voltage and the other of reversed or negative phase sequence. The generator cannot deliver power through the medium of the latter component, because the average product of the generator voltage and the negative phase sequence currents is zero. However, the volt-ampere product is important in being a measure of the effect of current unbalance on the system. Under this method, power charges are based on positive phase sequence power only, a further charge being made for the amount of unbalance determined from the readings of a negative phase sequence ammeter.

The measurement of positive and negative phase sequence components of an unbalanced three-phase system is based on the fact that if we diminish by 60 degrees the phase angle between any two vectors of such a system, then



POSITIVE AND NEGATIVE PHASE-SEQUENCE MEASUREMENTS
In each diagram the ohmic value of Z equals that of R; and the phase-angle of Z = 60°.

Fig. 37-8. Positive or negative phase-sequence volts. Fig. 37-9. Positive or negative phase-sequence amperes.
Fig. 37-10. Positive and negative phase-sequence volts. Fig. 37-11. Positive & negative phase-sequence amperes.
Fig. 37-12. Positive and negative phase-sequence watts.

the resultant of the modified vectors will be equal in magnitude to $\sqrt{3}$ times the positive phase sequence component of the system. If the phase angle between the vectors be increased by 60 degrees the magnitude of the resultant will be $\sqrt{3}$ times the negative sequence component.[8, 9, 10]

Fig. 37-8 shows the connections for directly measuring these components of an unbalanced voltage system. Two voltage transformers are connected in open delta, one of the secondary windings being reversed. Supplied from this combination are two impedances of equal ohmic value—one non-inductive and the other having a phase angle of 60 degrees. The resultant of the currents in these impedances is passed through a low-range ammeter of relatively low impedance. The current in this instrument will be proportional to the resultant of two of the line voltages, one being retarded by 60 degrees. If the latter voltage is lagging in respect to the former, the current in the instrument will represent the negative sequence component of the system. If the inductive burden be connected to the leading voltage, the indication of the instrument will represent the positive sequence component of the system.

In a similar manner an unbalanced current system may be resolved into its positive and negative phase sequence components by the connection shown in Fig. 37-9. Two current transformers are connected as shown to a burden containing two impedances of equal ohmic value, one having a phase angle 60 degrees greater than the other. If the impedance having the greater phase angle is connected to the leading phase with respect to the other, the ammeter reading will be proportional to the positive phase sequence component; and if it is connected to the lagging phase the reading will represent the negative phase sequence component.

It is possible to combine the networks so that positive and negative sequence magnitudes may be measured with a single set of instrument transformers. Such a combination for positive and negative phase sequence voltage is shown in Fig. 37-10, and a corresponding network for current measurement in Fig. 37-11. Networks have also been developed whereby phase sequence measurement may be made without the need for reversal of instrument transformers, so that other standard metering connections may remain undisturbed.

The positive and negative sequence voltages and currents of a circuit may be treated in every respect as ordinary a.-c. magnitudes, and may be combined in single-phase wattmeters, power factor indicators, reactive volt-ampere meters, etc., providing significant and important data as to circuit conditions. Connections of a positive phase sequence wattmeter are shown in Fig. 37-12.

[8]Measurement of Power in Polyphase Circuits. C. L. Fortescue; *Transactions A.I.E.E.*, Vol. 42 (1923), page 358.
[9]Power, Reactive Volt-Amperes, Power Factor. C. L. Fortescue; *Transactions A.I.E.E.*, Vol. 52 (1933), page 758.
[10]New Sequence System of Polyphase Meters. R. D. Evans; *Electrical World*, Vol. 81, Feb. 10, 1923, page 333.

MANUFACTURERS' NEW LITERATURE

In this department we each month list the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.

B288 **Color Analyzer.** This bulletin gives details of construction and lists the features of the Bausch & Lomb HSB color analyzer. A price list is also included. Bausch & Lomb Optical Company, Rochester, N. Y.

B289 **Vibrometer.** Leaflet give a brief description of the Davey Vibrometer Model 1. Electrocon Corp., 6 Varick St., New York, N. Y.

B290 **Vibrometer.** Leaflet describes Starrett Vibrometer No. 192. L. S. Starrett Co., Athol, Mass.

B291 **Resistance Thermometer.** Leaflet illustrates a direct reading resistance thermometer for industrial application. Albert A. Weiss & Son, 261 Vanderbilt Ave., Brooklyn, N. Y.

B292 **Amateur Microscope Equipment.** Small leaflet (3"x6") illustrates microscope equipment for the amateur. A large leaflet (6"x9", 16 pages) is addressed to dealers and bears the title "Putting the profits in microscopy." Bausch & Lomb Optical Co., Rochester, N. Y.

B293 **Power-Factor Control.** Bulletin GES-1012 is entitled "Here's Proof that Power-Factor Improvement Reduces Power Costs." 14 pages. General Electric Co., Schenectady, N. Y.

B294 **Relays and Switches.** A direct mail circular, which contains information on the Strowger line of communication, signaling and remote control apparatus. American Automatic Electric Sales Co., 1033 West Van Buren St., Chicago, Ill.

B295 **Portable Fractional Analysis Apparatus.** Circular No. 11 lists the special features and advantages of the equipment. Procedure is outlined and prices are listed. Podbielniak Industrial Research & Analytical Labs., 222 E. Superior St., Chicago, Ill.

B296 **Photograph Lens.** Leaflet illustrates the results obtained with the Convertible Protar Series of Lenses. Prices are given. Bausch & Lomb Optical Co., Rochester, N. Y.

B297 **Keep Down Power Bills.** This is discussed in Bulletin No. 534 issued by the Esterline-Angus Company, Indianapolis, Ind.

B298 **Resistors.** The June-July issue of the Ohmite News contains information on: New 100 Watt and 200 Watt "Dividohm Resistors, and New Heavy-Duty Tapswitch on Rheostat Cores." Ohmite Mfg. Co., 636 North Albany Ave., Chicago, Ill.

B299 **Electrically Heated Ladles.** Bulletin P-57 is an illustrated price list of various special ladles for heating waxes and compounds. Several styles and capacities are shown. Struthers Dunn, Inc., 125 N. Juniper St., Philadelphia, Pa.

B300 **Piston-Ring Expansion Joint.** Bulletin No. 211 gives considerable engineering data on the Adsco piston-ring expansion joint. It is claimed to fill a long-felt need in the high pressure piping field. American District Steam Co., North Tonawanda, N. Y.

B301 **Colored Optical Filter Glasses.** Bulletin 4892E gives in tabular and graphic form the following information on Jena colored optical filter glasses: specific gravity, hardness, reflection factor, and transmission values. Fish-Schurman Corp., 230 East 45 St., New York, N. Y.

B302 **Moisture Tester.** Leaflet describes instrument for determining moisture in granular materials, sand, coal, tobacco, cotton, wool, grain, paper, etc. Alpha-Lux Co., Inc., 192 Front St., New York, N. Y.

B303 **Optical Glass.** Properties of Jena optical glasses are listed in tabular form. (Bulletin printed in German) Fish-Schurman Corp., 230 East 45 St., New York, N. Y.

B304 **Rotary Switches.** Catalog No. 9 describes the Type R rotary control switches. Connection diagrams, sizes and prices are given. Roller-Smith Co., 233 Broadway, New York, N. Y.

B305 **Transparent Draft Gages.** Four-page bulletin describes a draft gage made of bakelite. Prices are given. F. W. Dwyer Mfg. Co., 565 W. Washington Blvd., Chicago, Ill.

B306 **Viscosity Regulator.** Bulletin No. 3307 describes a device for regulating viscosity. Some applications are: Heavy fuel oils for Diesel engines and burners, lacquer and varnishes, lubricating oils, sizings and coatings, printing inks, adhesives, and oil refinery blending and processing. Merritt Engineering & Sales Co., Inc., Lockport, N. Y.

B307 **Kathetron Out-Voltage Regulator.** Catalog No. 10 describes an electronic tube voltage regulator. Roller-Smith Co., 233 Broadway, New York, N. Y.

B308 **Micro Switch.** Four-page leaflet describes principle of the Burgess micro switch and lists applications. C. F. Burgess Laboratories, Inc., Freeport, Ill.

B309 **Pressure Atomizing Nozzles.** Bulletin 69A on nozzles gives complete data for use on water or oil. Detroit Lubricator Company, Detroit, Mich.

B310 **Micro Regulating Valves.** Bulletin describes principle of operation and lists sizes and capacities. Hauck Manufacturing Co., 126 Tenth St., Brooklyn, N. Y.

B311 **Combustion Control Regulator.** Bulletin 210 describes the M J L No. 27 regulator for combustion control. Morey & Jones, Ltd., 922 S. Hemlock St., Los Angeles, Calif.

B312 **Relays.** Bulletin No. 233 gives wiring diagrams, dimensions and contact rating for the various relays manufactured by the Eagle Signal Co., Moline, Ill.

B313 **de Forest Scratch Recording Strain Gage.** Bulletin No. 72 describes a new type of scratch extensometer, no larger than a latch key and costing less than $5. Instructions in its use and in the care and handling of the record strips is appended. Baldwin-Southwark Corp., Philadelphia, Pa.

B314 **Split Phase Motors.** Leaflet Type RWS is a complete leaflet on Holtzer-Cabot motors designed for use on office machines, fans, blowers, motion-picture projectors, generators, oil burners, electrical controls, medical apparatus, etc. Holtzer-Cabot Elec. Co., 125 Amory St., Boston, Mass.

B315 **Flow and Liquid Level Recorders and Regulators** are illustrated in Bulletin 5944. Details are given. Taylor Instrument Companies, Rochester, N. Y.

B316 **Oil Well Drilling Control.** Eight-page bulletin describes the Quintuplex drilling control instrument. It is made up of 5 instruments: the weight indicator, the supersensitive vernier weight indicator, the torque gage and the rotary table tachometer. Martin-Decker Corp., 3431 Cherry Ave., Long Beach, Calif.

(Continued on Page 197)

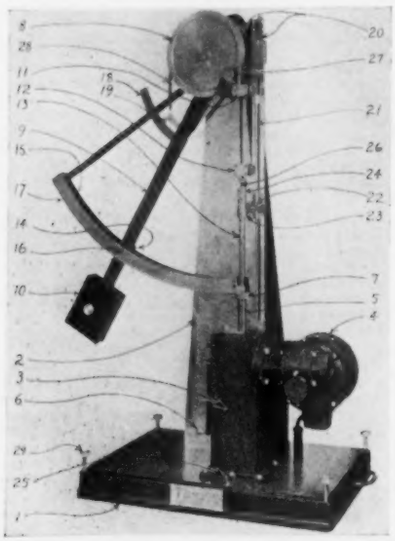
NEW INSTRUMENTS

Write Information Section, Instruments Publishing Company, for additional information.

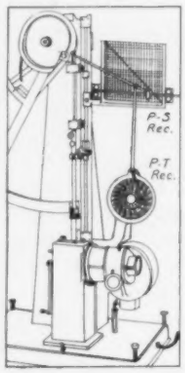
All-purpose Tester

Thwing Instrument Co.

AS its name indicates, this new instrument can be used for tension and stretch tests (set-up illustrated), for bending tests with a device for that purpose which permits various center-to-center distances; also for puncture tests, tearing tests, adhesion tests, etc., by using special attachments. Moreover, it can be adapted for other tests such as impact, "pick" (paper coating), etc. Top surface of base 1 and front surface of upright 2 are full-ground so that future devices and attachments can be applied at minimal cost. *Description and Operation*: To ribbed cast iron base plate 1 is screwed gear box 3 (for either motor drive 4 or belt drive) which provides reversing motion for pulling-screw 5 by means of manual reversing lever 6 or automatically by reversing collar 7. To chain wheel 8 are attached main pendulum 9 and selected weights 10. Upper grip 11 is secured by chain to chain wheel 8 whereas lower grip 12 is secured to extension rod 13 located in bore of pull-screw 5 and drilled to permit specimen lengths from 10 mm. to 180 mm. When screw travel is downward with a specimen between grips, pendulum inclines to left; when specimen breaks, pawls 14 fall into ratchet sector 15 so



that pendulum is held in place and its pointer 16 indicates force on scale plate 17 which is normally provided with two scales (various options) corresponding to weights used. At the same time, elongation is indicated on scale plate 18 by pointer 19 driven by rack-and-sector 20. Rack is moved by rod 21 attached to bracket and levers 22 secured to main screw and engaged by slide 23. When specimen breaks, sleeve 24 falls and releases trigger making contact between 22 and 23, thereby stopping further movement of elongation pointer. Located conveniently in front of gear box is toggle switch 25. To use bending-test device (not illustrated) pins 26 and 27 are withdrawn and a special bracket inserted instead of grips 11 and 12. A short length of chain 28 is provided also for hanging balance weights when it is desired to bring pointer 16 to scale zero, this pointer zeroing being assisted also by four leveling screws 29. *Recording Instruments*:—Two graphic devices optionally furnished are a Pressure-and-Stretch Recorder with rectangular chart, and a Power-Time Recorder with synchronous motor drive for round chart. The former autographs the load-elongation curve of individual test pieces; the latter provides a record of the rate of loading and its switch is interlocked with gear shifting arm 6. Both recorders are automatically disconnected when the test piece breaks. They are operable individually or together.



Manual A.-c. Voltage Regulator

Roller-Smith Co.

REMOTE control presents no difficulties with the new Kathetron Manual Regulator: the grid voltage circuit rheostat may be 2" in diameter and located at practically any distance. Accurate setting independent of load is said to be another characteristic. Available in almost any desired rating, this

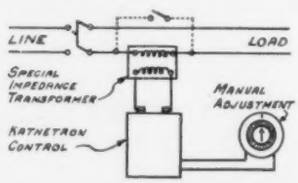


FIG. 1

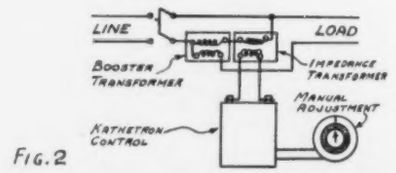


FIG. 2

new regulator is applicable in any a.-c. circuit where voltage is to be manipulated and is recommended "wherever a.-c. rheostats, resistances, reactances, multi-step transformers and similar apparatus are now used." Attainment of higher efficiency than with older regulators employing tubes is another claim, supported by published characteristic curves from which the following five comparisons are taken:

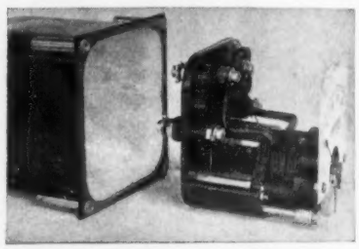
% load current.....	20	40	60	80	90
	EFFICIENCY, %				
Kathetron Regulator	60	81	88	93	94
Best older	45	66	75	80	83
Ordinary rheostat..	8	22	43	68	83

Like the Kathetron (automatic) Out-voltage Regulator (*Instruments*, July 1934, page 147) this device depends upon the new Kathetron hot-cathode rectifier with control grid in the form of an external band, permitting varying the applied potential without shifting the phase. This tube in itself constitutes an elementary regulator, but the new device utilizes it in a different manner. Fig. 1 shows the "impedance transformer" type of Kathetron Regulator. No booster characteristic being involved, its range is from slightly below normal voltage applied to load, down to 25% or less of normal. In another form, Fig. 2, the Kathetron Regulator is supplied so as to either boost or reduce the voltage applied from line to load over a range of about 50% each way. It then comprises the regulator arrangement of Fig. 1, working in conjunction with a booster transformer so as variably to adjust its boosting effect.

Smaller Square Instruments

Westinghouse Elec. & Mfg. Co.

ALTHOUGH the new Type K line of small indicating instruments in rectangular cases is intended primarily for power station miniature switchboards, supervisory control, etc., the scale length, accuracy, and insulation design are such as to permit more general use where small size is desirable. Movements are the same as those in the larger Westinghouse instruments, yet cases are 4" x 4¼" overall. Dials are illuminated. Cases are of flush mounting type, but arrangement affords access to



aid removal of mechanism, which is assembled on a molded composition subbase. Outer decorative cover is attached to an inside dust-proofing cover plate by spring snaps, permitting a pleasing front

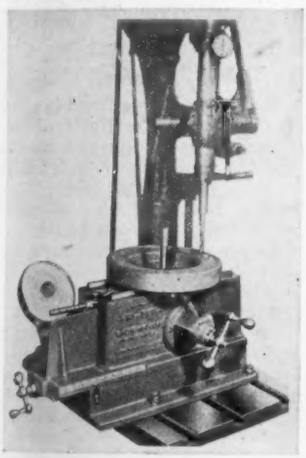
design, free from screwheads. D.-c. instruments (Type KX) have d'Arsonval elements. A.-c. ammeters and voltmeters (Type KA) are of repulsion moving iron type. Type KY wattmeters, frequency meters, and power factor indicators operate on electrodynamometer principle.

Static Balancers

Taylor Mfg. Corp.

FOR flywheels, pulleys, pump impellers, gears and similar shaped parts, these balancers are said to be "universal" in that they permit balancing various shaped or sized parts in quick rotation without a change in set up, the only adjustment required being a turn or two (by the fingers) of threaded portion of centering spindle. This adjusts weighing fulcrum to center of gravity of part to be balanced.

Unbalance can be corrected as close as 0.01 in.-oz. on the smaller models to 0.1 in.-oz. on the largest. Standard models handle parts as light as 1 oz. and as small as 1" o.d. and up to 48" o.d. weighing 600 lbs. Larger models special. Locating heavy spot is "almost instantaneous" through use of a sensitive spirit level. Weighing of unbalance is accomplished either by a hand-operated weighing beam or through an automatic weighing dial. Amount of unbalance having been determined, usual delay in calculating number of holes to be drilled and their depth is done away with by an automatic calculator (shown on the left), so that an ordinary drill press hand can operate these machines. Another feature is that if the particular spot where excess material is to be removed should prove to be a hard spot and making drilling difficult or impossible at that point, a turn of the left ball crank will move the part in or out (as desired) to a new position and the automatic calculator, moving in synchronism with the base, registers the drilling data for the new

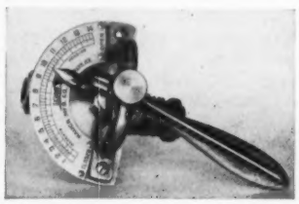


position. *Operation*: Part is placed on the base with centering spindle through its bore. (For various shapes and sizes of bores, bushings are provided.) A turn of right ball crank lifts part into balancing position; heavy spot tilts part; bubble in spirit level goes to opposite side. Heavy side is then swung on cradle to opposite weighing beam and unbalance is weighed. By turning left ball crank, part is moved so that drill will come directly over spot where excess material is to be removed. Calculator has moved with base all this time and operator reads number of holes to drill at the selected radius and their depth in thousandths. Right hand lever is turned back to first position, which lowers part onto frame and locks weighing mechanism. The drilling is then done. Right hand lever is again turned to right, again raising work into balancing position; weighing beam weight is set at zero and this checks the work. *Models*: In addition to those which can be used on any available drill press, production line models are built with integral base and drill head. One model, developed especially for the balancing of polishing wheels, where unbalance is compensated for by nailing lead slugs onto side of wheel, is considerably faster than method of balancing polishing wheels on "ways" and is said to be much more accurate.

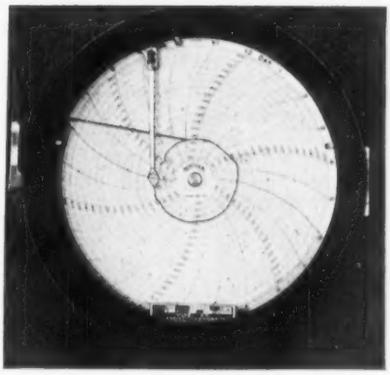
"Micro Regulating" Valves

Hauck Mfg. Co.

EXTREMELY close control of fuel flow to burners is obtained by new design in which opening is the orifice produced by conjunction of a longitudinal slot in plug and a circumferential slot in ring seat. Latter slot is a long



triangle, so that when plug slot is next to small end of ring slot, resulting orifice is minimal and when plug slot is next to large end of ring slot, opening is maximal. Inasmuch as 130° rotation of handle is required from closed to maximum orifice, an easily-read scale is made possible. *Micro Vernier Valve:* This permits "the greatest possible refinement of manual adjustment" inasmuch as worm-and-wheel operation replaces plain handle.



Recording Thermometers

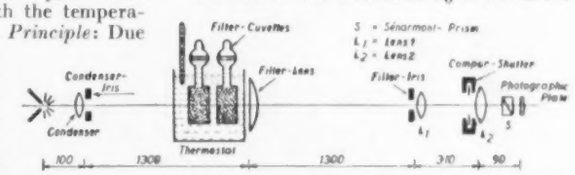
Moeller Instrument Co.

COMPRISING wall, flush-mounting and portable models; one- or two-pen instruments with electric or spring chart drive; remote-bulb or self-contained; back or bottom connected cases, and a complete assortment of bulbs with various sockets and fittings, this newest line of recording thermometers on the American market is made up uniformly of 10" round-chart instruments (12⅞" o.d.), all with mercury-in-steel tube-systems. A total of 43 standard charts is already available, their ranges extending from — 10° (F., C. or R.) to 1000°F., 500°C. or 400°R. Aluminum alloy cases, black hard rubber finish. Steel capillaries said to be made "under a new process which produces a tubing with a remarkably smooth bore of uniform diameter" are sheathed in seamless copper tubing (regularly finished in nickel white) which protects them against rust in exposed locations.

Christiansen-Weigert Monochromator Dispersion Filter

Fish-Schurman Corp.

ESSENTIALLY a projection cuvette filled with granular-glass and liquid mixture, for producing monochromatic light of high intensity, and of wave-lengths varying with the temperature of cuvette contents. *Principle*: Due to their differing dispersive power, the granular charge made from thoroughly homogeneous optical glass, and the organic liquid, show the same refractivity only for a very narrow spectral region (λ_0). Light of λ_0 will pass through the glass-liquid mixture without disturbance, exactly as through a solid glass plate; other wave-lengths are irregularly deflected and diffused, and cut off by an iris. Since temperature will considerably change the refractivity of the liquid but hardly that of the granular glass, any rise in temperature of the glass-liquid mixture causes a shift of λ_0 towards the short-wave end. Thus, by varying the temperature of the dispersion filter, monochromatic light of any desired wave length up to the limit of transmission of the liquid can be obtained, as for instance red at 15° C., yellow at 20°, green at 25°, blue at 40°, violet at 55° C.



Infra-red Glass

Fish-Schurman Corp.

TRANSMITTING the infra-red just below the visible, "Jena Type RG-9" is now being produced in blown sheet form as well as in optical glass. The sheet glass has the same transmission but is priced much lower, in order to meet demand for commercial photoelectric relays required to operate on invisible radiation (burglar alarms, etc.)

Two-gage Test Kit

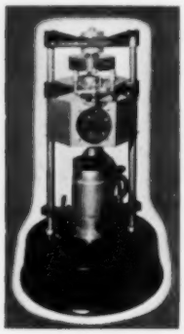
Marshalltown Mfg. Co.

FOR refrigerating machine service men, this instrument combines two round dial miniature size pressure gages—one 0-300, the other 30-0-60—in an attractively finished 3⅝"x3⅜" case. Both connections are ⅛" female. Cover can be removed to turn either dial in event of zero shift due to rough handling. Comes in serviceable leatheroid case.

Oiliness Tester

Sperry Products, Inc.

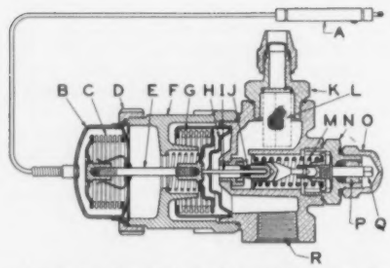
IN recent years various oiliness testers have been developed generally employing some friction-measuring principle. In the newly-announced "Adher-O-Scope" a thin film of oil on the periphery of a rapidly spinning rotor is subjected, by application of high centrifugal force, to a powerful disruptive process. All particles of oil not held by forces causing adhesion of oil to rotor are thrown off. Before the rotor is set spinning, its encircling band (on which oil is to be placed) is thoroughly cleaned and then weighed on an analytical balance. After proper distribution of a predetermined quantity of oil on its outer surface, the band is again weighed. Next it is put on the rotor, spun for twenty minutes at testing speed, removed and weighed again. The weight differential obtained represents the amount of oil still adhering to the band. It is said that this new method provides a correct quantitative determination of oiliness unaffected by other properties. *Principle*: Oiliness is said to be the ability of an oil to stick to a metal surface and lubricate—in a word, adhesion—not to be confused with cohesion (viscosity) or the ability of oil molecules to stick to each other. There is no definite relationship between viscosity and adhesion; an oil may be highly viscous without being adhesive, and vice versa.) In the course of the test procedure described above, the forces of cohesion are uniform throughout entire mass of oil. The instant, therefore, that centrifugal force overcomes cohesion, all oil so held to rotor is thrown off. As rotor speed is further increased, some oil held by adhesion begins to be thrown off. This oil consists of a number of layers, each a molecule thick, held to rotor much like iron filings to a magnet. These layers gradually yield, one by one, to increasing centrifugal force. *Readings*: It is said to be sufficient to measure oiliness, in terms of adhesion, only at two speeds of rotor—one a little above that at which oil held by cohesion is eliminated, the other at which a "substantial reduction" in the thickness of oil held by adhesion occurs. "This gives an index to measure the true ability of an oil to lubricate."



Thermostatic-expansion Valve

Detroit Lubricator Co.

FOR refrigerating applications this new "No. 785" operates on same principal as "No. 674" (*Instruments*, May 1934, page 97). New design has rated capacity of 8 tons on Freon and SO_2 and 16 tons on methyl chloride when operating at air-conditioning pressures. In operation the two bellows (see diagram) work against each other through the tie rod so that the needle opens only when the pressure in the power element exceeds the evaporator pressure. Valve thus admits just enough refrigerant to evaporator to maintain bulb "A" at a specified superheat. When bulb "A" is clamped to suction line, valve simply keeps evaporator completely refrigerated. Stainless steel parts include rod "E", push pin "I", seat holder and needle shank spring "M" and adjusting stem "Q". Needle and seat are tipped with "Delubaloy," said to be result of several years' search.

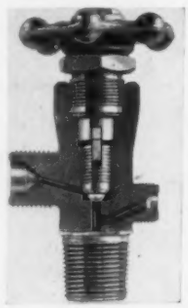


A—Thermostatic bulb. B—Thermostatic power element. C—Power element bellows. D—Hold down nut. E—Stainless steel tie rod. F—Bakelite extension. G—Body bellows. H—Baffle plate. I—Stainless steel push rod. J—"Delubaloy" needle and seat. K—Inlet connection. L—Removable strainer. M—Stainless steel spring. N—Removable body plug. O—Adjustment seal. P—Stuffing nut. Q—Adjusting stem. R—Outlet connection.

Ball-seat Valves

Air Reduction Sales Co.

MORE than 96% of all of "Airco" oxygen cylinders have recently been equipped with a new type of valve which, while it closely resembles the older type valve in appearance, differs in construction in that a hardened stainless steel ball forms the seat. The valves not only open and close easily but they are said also to possess superior sealing qualities and they do not corrode or score and cause leaks. For more than three years similar types of hardened stainless steel ball valves have been used on all Airco-DB torches, and it is said as a result of this experience that such torches rarely require valve repairs other than the occasional renewal of valve stem packing.



Thermostatic Valves and Pressure-control Valves

Fox Engineering Co.

SEVERAL new models of bellows-operated valves are announced. (1) Self-contained room temperature regulator in ranges 30-60°F., 50-90°F. or 60-80°F. operating on a 2° differential. (2) Remote-bulb temperature regulator in ranges 100-180°F., 120-180°F. or 200-400°F. operating on 5° or 10° differentials, in surface or immersion types. (3) Pressure regulator in 2 to 15 lbs. range for 15 to 100 lbs. working pressure, with 3- to 5-lb. differentials. All are especially designed and constructed for oil burner control.

Valve Operator in Explosion-Resisting Housing

Automatic Temperature Control Co.

FOR applications where motorized valves must work in the presence of an explosive atmosphere *and* where it may be necessary to open the housing to make adjustments or to lubricate the equipment, "Type 2 Controller" can now be supplied in an explosion-resisting housing as shown, this housing being divided diagonally into two flanged parts with a width of face in accordance with specifications of Underwriters' Laboratories, the flange faces being machined and bolted together without a gasket, so that the force of an internal explosion would be dissipated and the resultant flame cooled and snuffed out as the gases pass out between the machined faces of the castings, thus preventing the possibility of a plant explosion and also making for greater accessibility of the working parts. "Type 2 Controller" can be supplied with a single valve for liquids or gases as shown, or with the valves operated as a unit—for fuel-air ratio applications, etc.

Dial Indicator for Strain, Crankshaft Distortion, etc.

The L. S. Starrett Co.

ORIGINALLY designed in collaboration with the Hartford Steam Boiler Inspection and Insurance Co., the Hartford Steam Boiler Engine Strain Gage has a range of 2¼" to 18" obtained by means of ten rods and one extension. Rods are marked to designate approximate overall length of the gage. Indicator has movable bezel to adjust dial in relation to hand. Dial is graduated in thousandths and reads from 0 to 0.020 to 0, one turn equaling 0.040. This gage makes it possible to check bearing alignment or undue deflection of shaft without having to dismantle engine. Usable on all Diesel engine shafts as well as center-crank shafts of any type of engine or compressor. Can also be applied as a strain gage on engine frames while engine is in operation: comparison between readings obtained at top and at bottom position indicates misalignment of cylinder and frame. With a special spring tension in dial indicator, the gage is self sustaining in any position without sacrificing rigidity, leaving operator's hands free. Contact points are conical (about 90°) hardened and ground to sharp points.

Colorimeter Tubes

Fish-Schurman Corp.

FOR use in various standard colorimetric instruments these new cylindrical tubes are made with window fused directly to chemically resistant "Jena" glass. Two styles: plain or with stopcock.

"Sight Meter" Voltmeter

General Electric Co. and Weston Elec. Instrument Corp.

CONVERTING volts into light and light back into volts, this device, developed by G. S. Merrill, of the Nela Park Eng. Dep't of G-E at Cleveland, employs the Weston Photronic Footcandle Meter, together with a carbon filament lamp, a small composition container, and a 1-ft. rubber-covered extension. Carbon lamp, used because its light varies more with voltage than that of a tungsten-filament lamp, is housed in the container and is adjustable by lock-nut on threaded fiber tube. Container has five small openings: four on the side to facilitate reading and one at top of indicator cone, bottom of which is placed over Photronic cell. Conversion scale shows standard relation of footcandles and volts. In determining the socket voltage of the lighting system (a.c. or d.c.) Indicator is connected to circuit, its bottom placed over the Photronic cell of the "Sight Meter" and the voltage determined by reading footcandles and referring to conversion scale.

Heating Rate Control for Electric Furnaces

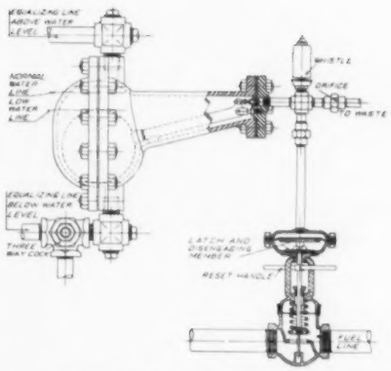
Lindberg Steel Treating Co.

DEFORMATION of gears and other steel parts required to hold shape "occurs in the heating rather than in the quenching," according to some metallurgists who further declare that "slow gradual heating eliminates entirely the tendency for the steel to go out of shape." This new device is not designed to replace furnace temperature controllers but to provide regulation (instantly adjustable at will) of the maximum B.t.u. supply in a given time. Essentially it is a continuously-repeating time-cycle switch with a standard period of one minute. Thus, if small parts are charged into a 100 kw. furnace and if the metallurgist desires a maximum heating rate of 40 kwh., he sets pointer at "40" on the percent scale of the Lindberg Control, which then will cause the current to be "on" 24 seconds and "off" 36 seconds in every minute. A demand meter would then register 40 kw. over one hour—exactly as if the furnace had ten 10 kw. elements of which four had been "on" and six "off" continuously. It is reported that several large electric furnace manufacturers have adopted this device as standard equipment and that the government specifies it in its electric furnace orders.

Low-water Fuel Cutout

Davis Regulator Co.

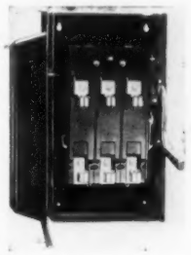
FOR gas-fired field boilers, this new automatic device functions when water level becomes dangerously low, and stops further steam generation by shutting off fuel. An alarm is sounded. Valve must be reset by hand before fuel can again flow to burners. Insurance companies are said to have listed this cutout as an "approved safety appliance."



100 and 200-amp. Switches

Square D Co.

ADDITION of 100- and 200-amp. "Type A" switches completes the line up to and including 200-amp. switches in either standard sheet metal boxes or cast aluminum enclosures, with cast iron enclosures optional, if specified. The new numbers resemble the 30 and 60-amp. switches of this line, with added features for the higher capacities. They are quick-make, quick-break, with interlocked covers and elevated removable bases. Enclosures are smaller than those of conventional type of knife switches. Among features are double-break contacts with steel spring reinforcements assuring constant pressure on contacts for reduced heating. Entire line now includes 230 volts a.c./250 volts d.c. and 575 volts a.c./600 volts d.c. switches in two or three poles, 3-wire solid neutral and 4-wire solid neutral, fusible and not fusible. Cast aluminum or cast iron enclosures are weatherproof or dust-tight.



Holder for 3-light Lamps

General Electric Co.

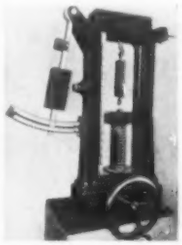
THERE is announced a special lamp holder and a six-ampere 125-volt canopy switch designed for three-light Mazda lamps. Holder and switch provide three degrees of lighting intensity as desired from the lamp filaments,

and do away with need of resistance devices used to regulate lighting intensities of single-filament lamps. Control is obtained in the single units by a special canopy switch; in multiple units, control may be more conveniently wired to a wall-type switch.

Pendulum-indicating Spring Testers

Coats Machine Tool Co.

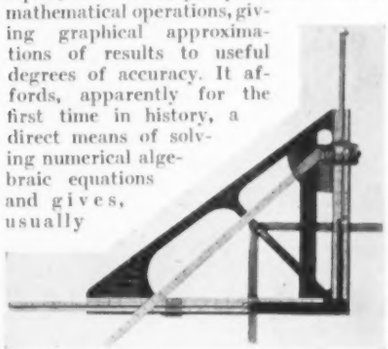
IN making compression tests with previous models (*Instruments*, Dec. 1929, pages 465-466) the spring was pressed up against an upper compression plate which actuated the multiple-beam weigher scale at the top of the machine. New "Type DN" design has no upper compression plate: a screw-operated cross-head bears down on spring, compressing it against a lower compression plate suspended from a single-beam weigher scale and guided vertically in ball races. This new method of always pulling on the beam—in compression as well as tension tests—is said to be preferable to older one. New machine is built in four capacities up to 6000 lbs., each in two lengths, making a series of eight different machines employing the new principle.



Calculating Instrument

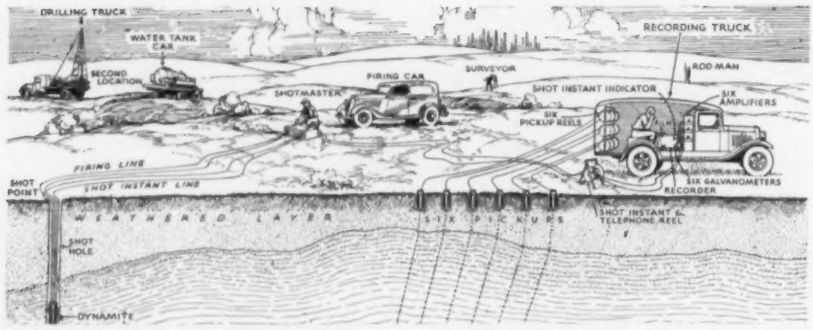
By Barrett R. Wellington*

FIRST contrivance of its kind to receive a patent from the U. S. Gov't, and based on novel geometrical principles, the Trianalyst performs various mathematical operations, giving graphical approximations of results to useful degrees of accuracy. It affords, apparently for the first time in history, a direct means of solving numerical algebraic equations and gives, usually



with little or no incidental computation, the roots of quadratics, cubics and biquadratics, as well as the roots of certain restricted forms of still higher equations and various classes of simultaneous equations. In addition, one, two or three settings of the parts present the solution of any one of numerous complicated formulae involving multiplication, division, addition, subtraction, and powers and roots of numbers expressed in one moment of combination. Some of these comprise each as many as twenty arithmetical operations. Logarithms are read off directly. By reason of its triangular form the Trianalyst functions also in the trigonometric field. This July 1934 invention is distinct from a prior calculating device of the same inventor patented in 1932. The new model as now made weighs about ten ounces and can do a much greater number of determinations.

*Troy, N. Y.



Reflection Method Geophysical Prospecting Equipment

American Askania Corp. and Heiland Research Corp.

IT is known that the seismic reflection method (timing and analyzing echoes of dynamite shot) permits highest accuracy—sometimes better than by actually drilling wells—but no reliable equipment was commercially available. The equipment now announced is complete, yet it all goes in one Ford delivery sedan, cutting costs in many ways. It consists of (a) 6 pick-ups, 6 reels, 6 amplifiers (in 2 boxes), 2 battery boxes and a photographic recorder with 6 galvanometers, shot instant transmission and timing system; (b) accessories such as field telephones and duplex wire reels, firing box, developing outfit, etc.; (c) supplies such as electric lamps, batteries, 100-foot rolls of photographic paper, etc.; (d) spare parts in numbers depending on projected expeditions. Note—radio instead of wire-circuit telephone is optional. *Multiple Pick-up Feature*: Theoretically, reflections could be recorded by one vibration-detector alone. However, in that case, it would be impossible to identify a seismic impulse in the record as a reflection. With a number of pick-ups, the reflected impulse reveals its identity by reason of the almost vertical incidence of the echo, while other waves arrive at each receiver at different intervals. The number of seismographs found to be the most practical is six. *Pick-ups*: Electromagnetic type vibration detectors "requiring no adjustment whatever in the field . . . have been handled under the most severe field conditions without requiring opening of the casing." Calibrated for natural frequency, damping and electrical sensitivity as well as phase. *Amplifiers*: 3-stage resistance-coupled, with adjustable filtering for passing only desired frequencies. Response curves of each are determined beforehand in laboratory and balanced. *Recorder*: Essentially a chronograph with 6 galvanometers and camera. Each galvanometer is a separable unit. Camera is so made that paper may be readily changed. Indicator shows how much paper has been exposed. Record may be taken in daylight. On request, recorder may be furnished for daylight loading and daylight developing. Optical system furnishes clear and legible records, provision is made for simultaneous photographic recording *and* visual observation. Entire recorder is self contained, requires only a storage battery for operation. Self-contained timing system projects time lines every 0.01 second across entire width of paper; is automatically turned on at the instant of firing. Rate may be checked by a calibrated fork (accessory). Each of the 6 independent galvanometers is separately adjustable for vertical and horizontal position of light spots. Sensitivity (adjustable) is of the order of 0.1 to 0.2 ma./mm. Moment of inertia is exceedingly small and natural frequency high. Sensitivity tester for all galvanometers permanently installed on panel.

Moisture Content Indicator

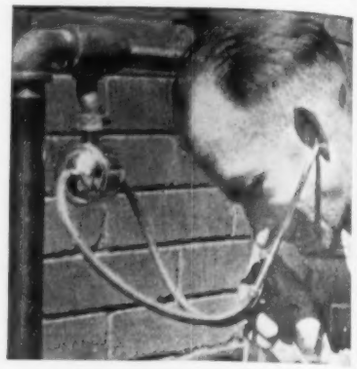
R. Fuess, Inc.

PRINCIPLE is similar to that of familiar "sword" hygroscope inserted in bale of cotton, stack of fibrous sheets or pile of printing stock: relative humidity of air confined next to material is function of moisture content of material. Design, however (German patent applied for), permits application of this principle to small quantities: instrument consists of rectangular box about 6″ long, with hair bundle inside lid and dial indicator on top. Sample is stuffed into box, 10 or 15 minutes allowed for attainment of equilibrium conditions, and reading taken. Unique feature is that by filling box half-full of a solution producing a known percent humidity, hygroscopic measuring element may be calibrated accurately and instrument can then serve as a reliable Standard.

Gas Leak Stethoscope

E. R. Gilmore

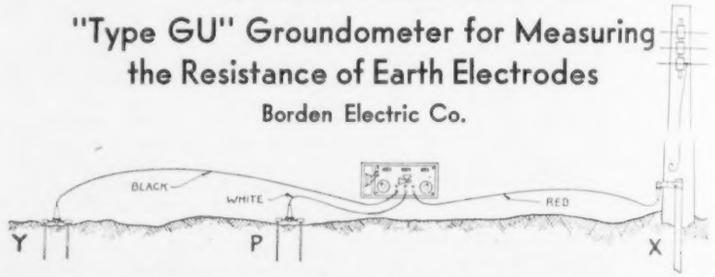
WITH a little experience, anyone can locate a leak within a few feet by means of this new device, which may be attached to main or drip and has a chamber so constructed



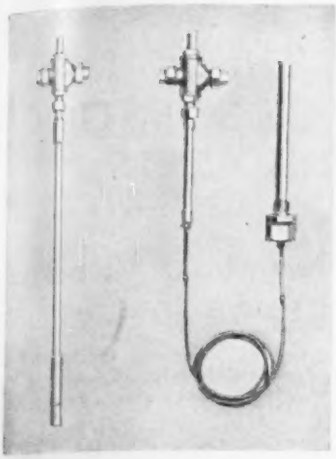
as to collect and amplify leak vibrations. Consumers who by-pass meters are found out, because sounds of appliances are stopped by meters. Water in the line is unmistakably detected. Low-pitched roar of a district regulator does not (except close by) drown out characteristic bee-buzz sound of leak.

"Type GU" Groundometer for Measuring the Resistance of Earth Electrodes

Borden Electric Co.



EARLIER models of the Groundometer (see *Instruments*, August 1929, pages 293-294) employed conventional ground ohmmeter circuit, with one test electrode. The "voltmeter-ammeter" method, placing a third ("P") electrode between X and Y and measuring the potential drop between P and each of the others, makes it possible to determine how much of the total resistance is attributable to each earth path. It is said, however, that the usual equipment was heavy, expensive, easily damaged, and sometimes requiring two men's time for half a day to make a single test. All this has been changed, it is said, by the development of the new direct-reading, portable Groundometer and accessories. The complete outfit now weighs slightly over 15 lbs. and is available in a single carrying case approx. 12″ x 8″ x 6″ overall. It indicates on a dial the correct electrode resistance regardless of the resistance of the reference electrodes, and makes it possible to use small reference electrodes regardless of their high resistance values. Duplex reference electrodes may be inserted in soil without tool, and easily withdrawn with one hand. They serve as reels on which to wind test leads when not in use. Taking the reading, after equipment has been transported to test point, test electrodes installed and connections completed, consumes so little time, with a direct reading instrument, that it is not an important economy factor. Important factors are size and weight of outfit as these determine transportation facilities, number of men and total time. "Type GU" is strictly a one-man outfit. A lineman can take it up a transmission tower and measure the tower resistance by using a grounded line wire for the reference electrode. Only ordinary intelligence, it is said, is required for its operation. It has no delicate parts or moving instrument elements. Operating instructions for ordinary testing are contained in the lid. Electrode resistance is read on a 5″ scale with 100 equal divisions of 1 or 10 ohms. It is not intended for accurate readings below 10 ohms. Resistance of Y may be $< 400 \times$ resistance of X which is being measured. Resistance of P may be as high as 30,000 ohms.



Temperature Regulators

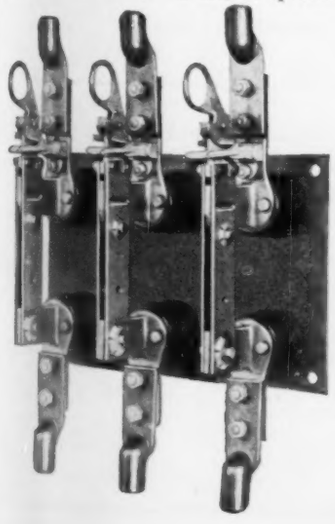
Sarco Co., Inc.

TWO new instruments have been added to this maker's line of self-operating temperature controllers. *Type KR-15* (left): For control of brine cooling coils, a compact and inexpensive unit. Valve is "packless," so that frosting in service cannot cause sticking. Setting key furnished. *Type TR-20* (right) a new junior model of the Sarco tank regulator, is made in three sizes, ⅜", ½" and ¾"; has a small union connection bulb and a short length of flexible connecting tubing. Designed to make possible the use of automatic temperature control on equipment for which the standard regulator was too costly, it has found application in hospitals for blanket warmers and sterilizers, in plastics factories for controlling cooling water for molds, and in textile mills in connection with humidifying apparatus.

Indoor Disconnecting Switches

General Electric Co.

FEATURING silver-to-silver line-pressure contacts, a new line of indoor disconnecting switches, with ratings as high as 1200 amperes at 5000 volts, is announced. The silver, applied to the contacts by a special G-E process which produces a surface of unusual wearing qualities, is said to eliminate oxidation troubles. A 30,000-operation test failed to harm the silver-contact surfaces. Complete line includes hook-operated, single- and double-throw, double-blade transfer switches with half- or full-capacity blades, single-throw tandem transfer switches with full-capacity blades, and group-operated switches controlled manually or electrically. The single- or multi-pole switches are mounted on compound insulators and metal bases.



Industrial Humidity Indicator

Fee & Stemwedel

IMPROVEMENTS claimed over conventional types employing hygroscopic elements are chiefly found in the measuring element of this new "Airguide" industrial model. Element is a metal-and-fibre spiral so designed and mounted that even extreme and sudden changes in relative humidity do not overstress it. Usual

limit of error ± 3% or one-tenth of error occurring when using wet- and dry-bulb instrument under certain conditions. Maximum safe temperature, 125°F. Temperature compensation is complete at 70°F. and good as far down at 33°F. and up to 95°F. Instrument may however be used below 32°F. by being reset. Lag is inappreciable at usual room temperatures. No aging effects have been observed. Diameter, 4⅝". Rugged black, ivory or chromium finished case.

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Manufacturers' New Literature

(Continued from page 191)

B317 **Strobo-Mecn** is a small portable, spring wound stroboscope. Weight 10 oz., diameter 2¾ inches. F. Ducasse, 25 West 54th St., New York, N. Y.

B318 **Air-Acetylene Torch.** New 8-page illustrated booklet entitled "101 Uses for the Air-Acetylene Flame" describes the outfit necessary and discusses the advantages of the process. All repair men whose work includes soldering and brazing will want this bulletin. Linde Air Products Co., 30 E. 42nd St., New York, N. Y.

B319 **Whittemore Strain Gage.** Bulletin No. 71 replaces an earlier edition on the same subject. A section of instruction in its use is included. Two sizes are built: one having a 2" gage length and the other a 10" gage length. Baldwin-Southwark Corp., Philadelphia, Pa.

B320 **Weight Recorder.** Bulletin No. 7 describes the Abercrombie-Shimex weight recorder. The instrument indicates the load on the hook directly in thousands of pounds regardless of the cable arrangement or cable size. Cameron Iron Works, Houston, Tex.

B321 **Recording Thermometer.** Four-page leaflet describes the Model 500 Motoco recording thermometer, single pen, either portable with strap handle and with bulb mounted at back of case; or wall mounting with 5 ft. of double-braided flexible capillary tubing. Approximate weight 4 lbs., case dimensions 7"x7"x2¾". Moto Meter Gauge & Equipment Corp., Chrysler Bldg., New York, N. Y.

B322 **Telemeters.** Bulletin 73, descriptive of the McCollum-Peters electric telemeter, includes a discussion not only of the adaptations but also the limitations of this type of equipment, the latter being discussed under the subjects of hysteresis, temperature effects, etc. Baldwin-Southwark Corp., Philadelphia, Pa.

B323 **Bakelite Review.** Vol. 6, No. 2 illustrates the application of molded Bakelite to new instruments of Spencer Lens Co., Gamewell Co., and National Electric Instrument Co. Bakelite Corp., Bound Brook, N. J.

B324 **Safety Float Valves.** Bulletin No. 70 describes these valve assemblies which combine in one unit a strainer, constant level valve, safety trip mechanism and vented metering valves. The CRC-234 model will control fuel "delivery" head pressure against a full "supply" of 12 ft. or less. Detroit Lubricator Co., Detroit, Mich.

B325 **Flow Indicator.** Bulletin 208 describes the M J L flow indicator and lists its applications. Price list is given. Morey & Jones, Ltd., 922 S. Hemlock St., Los Angeles, Calif.

B326 **Torsion Impact Testing Machine.** Bulletin No. 78 describes the Carpenter torsion impact testing machine, tells how it functions and reveals by means of graphs some of the results found in tests of hardened steels. A bibliography on impact testing is appended. Baldwin-Southwark Corp., Philadelphia, Pa.

B327 **Mercury-in-steel Thermometers.** 48-page catalogue describes various models furnished by Negretti & Zambra, 38 Holborn Viaduct, London, E. C. 1, England.

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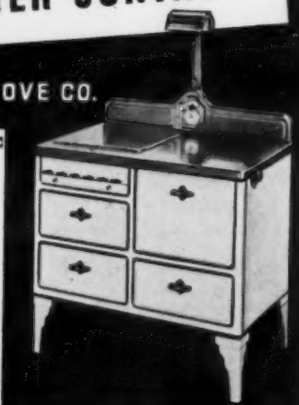

Chace Bimetal is the active element in many oven thermostats on both gas and electric ranges. Installed within the oven chamber Chace Bimetal responds to the slightest change in temperature and by its bending movement controls the fuel supply, thereby maintaining oven temperature at any desired range.

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Note on a Precision Variable Condenser for Direct Measurement of Extremely Small Capacity Changes
Effect of Treatment of the Surfaces of Calcite Crystals Upon the Resolving Power of the Two-Crystal Spectrometer
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Foxboro Co.
Pioneer Instrument Co.

COILS
Resistance, Inductance,
Special
General Electric Co.
General Radio Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Ward Leonard Elec. Co.

COIL TESTING EQUIPMENTS
General Electric Co.
Kurman Electric Co.
Roller-Smith Co.
Tinius Instrument Co.

COLORIMETERS
Bausch & Lomb Opt. Co.
General Electric Co.
Tinius Instrument Co.

COMBUSTION CONTROL EQUIPMENT
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Pioneer Instrument Co.

COMMUNICATION MEASURING INSTRUMENTS
General Radio Company
Rawson Elec. Inst. Co.
Roller-Smith Co.
Shallcross Mfg. Co.

COMPARATORS
Gaertner Scientific Corp.
General Electric Co.

COMPASSES
Pioneer Instrument Co.
Taylor Instrument Cos.

CONDENSERS—Electrical
General Electric Co.
General Radio Co.

CONDUCTIVITY METERS
Indicating, Recording, Controlling
Rawson Elec. Inst. Co.
Roller-Smith Co.

CONTOUR MEASURING PROJECTOR

CONTROLS, AUTOMATIC
Combustion
Bailey Meter Co.
Condensation
Bristol Company
Taylor Instrument Cos.
Damper
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Feed Water
American Meter Co.
Bailey Meter Co.
Bristol Co.
Brown Instrument Co.
Foxboro Co.
Filter Rate
Bristol Company
Brown Instrument Co.
Foxboro Co.
Flow
American Meter Co.
Bailey Meter Co.
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Humidity
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Humidity & Temperature
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Lighting
Weston Elec. Inst. Corp.
Liquid Level
American Meter Co.
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Materials Testing.
Baldwin-Southwark Corp.
Pressure & Vacuum
American Meter Co.
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Pyrometer
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.
Rate-Volume
American Meter Co.
Foxboro Co.
Refrigeration
Bristol Company
Brown Instrument Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Specific Gravity
Bailey Meter Co.
Tachometer
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Weston Elec. Inst. Corp.
Temperature-Time
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Thermometer
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.
Thermostat
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.
Time
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Vacuum
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Valve—Motor Operated
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
Voltage A.C.
Ward Leonard Elec. Co.
Water Level
American Meter Co.
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.

COUNTERS—Magnetic
Thwing Instrument Co.
Revolution
Bristol Company
Brown Instrument Co.
Pioneer Instrument Co.
Stroke
Bristol Company

CREEP TESTER

CUBIC FOOT BOTTLES
American Meter Co.

CURRENT RECORDERS
Bristol Company
General Electric Co.
Roller-Smith Co.

CYCLE CONTROLLERS
Bristol Co.

CYCLE COUNTERS
General Radio Co.

CYCLOMETERS

DAMPING TESTER

DEFORMETER (Beggs)

DEMAND METERS
Gas
Foxboro Co.
Electric: Indicating, Recording, Printing
General Electric Co.

DIMMERS
Ward Leonard Elec. Co.

DIVIDING HEAD
Optical

DIVIDING MACHINES
Gaertner Scientific Corp.

DRAFT GAGES—See Gages

DYNAMOMETERS
General Electric Co.
Rawson Elec. Inst. Co.
Weston Elec. Inst. Corp.

EARTH CURRENT METERS
Rawson Elec. Inst. Co.
Roller-Smith Co.

ELECTRIC TELEMETERS—See Remote Metering Equipment

ELECTRIC WAVE FILTER SECTIONS
General Radio Company

ELECTROMETERS

ELECTRONIC METERS
General Electric Co.
General Radio Co.
Rawson Elec. Inst. Co.

ENGINE INDICATORS

ENGINE REVOLUTION COUNTERS

EXTENSOMETER

FATIGUE TESTERS

FAULT FINDERS
Roller-Smith Co.
Weston Elec. Inst. Corp.

FIELD RHEOSTATS
Ward Leonard Elec. Co.

FLASH & BURNING POINT TESTERS
Taylor Instrument Cos.

FLOW METERS
Indicating
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Pioneer Instrument Co.
Indicating & Recording
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Integrating & Recording
American Meter Co.

FLUE GAS ANALYZERS
Brown Instrument Co.

FLUXMETERS
Rawson Elec. Inst. Co.

FOOT-CANDLE METERS
Weston Elec. Inst. Corp.

FREQUENCY METERS
Indicating
General Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.
Recording
Bristol Company
General Electric Co.
Standards
General Radio Co.

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Bristol Company
Taylor Instrument Cos.
Wilbin Instrument Co.

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Cylinder
Deformation
Dial
Differential Pressure
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Draft
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Drill
Bausch & Lomb Optical Co.
Flow
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Liquid Level
American Meter Co.
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
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Thwing Instrument Co.
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Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
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Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Pressure & Vacuum
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Profile
Rain
Taylor Instrument Cos.
Recording—Distance
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
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General Electric Co.
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Thickness
Vacuum
General Electric Co.
Taylor Instrument Cos.
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Brown Instrument Co.
Foxboro Co.
Wind
Bristol Company
Brown Instrument Co.

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Brown Instrument Co.
General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Weston Elec. Inst. Corp.

GAS ANALYTICAL METERS
Electrical
Brown Instrument Co.

GAS FLOW INDICATORS
American Meter Co.
George Sidney Binckley

GAS LEAK INDICATORS
Taylor Instrument Cos.

GAS-METERS
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.
Dry Test
American Meter Co.
Wet Test
American Meter Co.

GOVERNORS
Pressure
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Taylor Instrument Cos.
Pump
Bailey Meter Co.
Taylor Instrument Cos.
Water Wheel

GRAVITOMETERS
American Meter Co.
George Sidney Binckley
Thwing Instrument Co.

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Roller-Smith Co.
Weston Elec. Inst. Corp.

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HARDNESS TESTERS

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General Radio Co.
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Roller-Smith Co.
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Indicators
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Shallcross Mfg. Co.
Weston Elec. Inst. Corp.
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General Electric Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Weston Elec. Inst. Corp.
Testing Devices
General Electric Co.

HOUR COUNTERS
Weston Elec. Inst. Corp.

HUB ODOMETERS

HUMIDITY CONTROLLERS
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Wilbin Instrument Co.

HUMIDITY RECORDERS
Wet & Dry Bulb
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.

HYDROGEN ION METERS

HYDROMETERS
Taylor Instrument Cos.

HYGROMETERS
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

ILLUMINOMETERS
Weston Elec. Inst. Co.

INDICATORS—See Gages

INDUCTANCES
General Radio Co.

INSTRUMENT CALIBRATION AND REPAIRS
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

INSTRUMENT TRANSFORMERS
General Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.
Split Core
Roller-Smith Co.
Phase Shifting

INSULATION TESTING EQUIPMENT
General Electric Co.
Roller-Smith Co.

INTERFEROMETERS
Gaertner Scientific Corp.

KEYS AND SWITCHES
General Radio Co.

LABORATORY RHEOSTATS
Ward Leonard Elec. Co.

LACTOMETERS
Taylor Instrument Cos.

LENSES
Bausch & Lomb Opt. Co.

LEVELS
Centering
Engineer's, Wye, Precision
Prism
Taylor Instrument Cos.

LIQUID LEVEL RECORDERS
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.

MAGNETIC INSPECTORS
Kurman Electric Co.

MAGNETIC RELAYS
Kurman Electric Co.
Roller-Smith Co.
Ward Leonard Elec. Co.

MAGNETOMETERS
Roller-Smith Co.

MANOMETERS
Bailey Meter Co.
George Sidney Binckley
Bristol Co.
Brown Instrument Co.
Foxboro Co.

MASTER CLOCKS
General Electric Co.

MEASURING MACHINES
Gaertner Scientific Corp.

MEGOHMMETERS
General Radio Co.
Roller-Smith Co.

MEGOHM VOLTMETERS
Roller-Smith Co.
Weston Elec. Inst. Corp.

MICROAMMETERS
General Electric Co.
Rawson Elec. Instru. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

MICROFARADMETERS
General Radio Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

MICROMETERS
Gaertner Scientific Corp.

MICROSCOPES
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Bausch & Lomb Opt. Co.
Brinell
Gaertner Scientific Corp.
Measuring
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.
Metallographic
Bausch & Lomb Opt. Co.
Petrographical
Bausch & Lomb Opt. Co.

MICROTOMES
Bausch & Lomb Opt. Co.

MILLIAMMETERS
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General Electric Co.
General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

MILLIVOLTMETERS
Bristol Company
Brown Instrument Co.
General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Weston Elec. Inst. Corp.

MIRRORS
Bausch & Lomb Opt. Co.

MODULATION METERS
General Radio Co.
Weston Elec. Inst. Corp.

MOISTURE METERS
General Radio Co.

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Bristol Company
Foxboro Co.

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Roller-Smith Co.
Ward Leonard Elec. Co.

MULTIMETERS
Rawson Elec. Inst. Co.
Shallcross Mfg. Co.

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Bristol Co.
Foxboro Co.

MULTIPLIERS
General Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

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General Radio Co.

OHM METERS
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Rawson Elec. Inst. Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Weston Elec. Inst. Corp.

OIL TESTING APPARATUS
General Electric Co.
Taylor Instrument Cos.

OPERATION RECORDERS
Roller-Smith Co.

Electrical
Bristol Company
Brown Instrument Co.
Foxboro Co.
Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.

OPTICAL PARTS
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American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.

Integrating
American Meter Co.

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Bailey Meter Co.

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Weston Elec. Inst. Corp.

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General Radio Co.

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General Electric Co.

Cathode Ray
General Electric Co.
General Radio Co.

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Gaertner Scientific Corp.

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General Electric Co.

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Kurman Electric Co.
Weston Elec. Inst. Corp.

PHOTO-ELECTRIC COLOR ANALYZERS
General Electric Co.
Thwing Instrument Co.

PHOTO-ELECTRIC COLOR COMPARATORS
General Electric Co.
Thwing Instrument Co.

PHOTOGRAPHIC EXPOSURE METERS
Weston Elec. Inst. Corp.

PHOTOMETERS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

PHOTO-MICROGRAPHIC EQUIPMENT
Bawson Elec. Instru. Co.

PITOT TUBE METERS
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.

PLANIMETERS
Automatic Flow Record
Brown Instrument Co.
Foxboro Co.

Linear
Brown Instrument Co.

Radial
Bailey Meter Co.
Bristol Company
Foxboro Co.

Square Root
George Sidney Binckley
Foxboro Co.

POLARISCOPES
Gaertner Scientific Corp.

POSITION RECORDERS
Brown Instrument Co.
Bristol Company
Foxboro Co.
Taylor Instrument Cos.

POTENTIOMETERS—
Indicating
Brown Instrument Co.
General Electric Co.
Thwing Instrument Co.

Recording & Controlling
Brown Instrument Co.
Thwing Instrument Co.

Standard Cell Comparing
Fousner Type

POWER FACTOR METERS
General Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

PRESSURE RECORDERS
American Meter Co.
Bailey Meter Co.
George Sidney Binckley
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

PRISMS
Gaertner Scientific Corp.

PROCESS TIMING & SIGNALING INSTRUMENTS
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

PROVERS
American Meter Co.

PROTRACTORS
Optical

PSYCHROMETERS
Recording
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

Sling
Taylor Instrument Cos.

PYRHELIOMETERS—
Weather Bureau Type

PYROMETERS
Optical

Radiation
Indicating
Brown Instrument Co.
Taylor Instrument Cos.
Thwing Instrument Co.

Recording
Brown Instrument Co.
Taylor Instrument Cos.
Thwing Instrument Co.

Thermo-electric
Immersion
Bristol Company
Brown Instrument Co.
Foxboro Co.
Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.

Indicating
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.

Recording and Controlling
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.

Surface Contact
Bristol Company
Brown Instrument Co.
Taylor Instrument Cos.
Thwing Instrument Co.

PYROMETER CALIBRATING SETS
Thwing Instrument Co.

RADIO FREQUENCY OSCILLATORS
General Radio Company

RADIO SET ANALYZERS
Weston Elec. Inst. Corp.

RADIO TEST PANELS
Shallcross Mfg. Co.
Weston Elec. Inst. Corp.

RADIO TUBE CHECKERS
General Radio Company
Weston Elec. Inst. Corp.

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REGULATORS—See Controls

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Kurman Electric Co.
Roller-Smith Co.
Ward Leonard Elec. Co.
Weston Elec. Inst. Corp.

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Burgess Labs., Inc., C. F.
Kurman Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

Vacuum Contact
Burgess Labs., Inc., C. F.

Vacuum Tube
Burgess Labs., Inc., C. F.

REMOTE METERING EQUIPMENT
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Bailey Meter Co.
Bristol Company
Brown Instrument Co.
General Electric Co.
Pioneer Instrument Co.

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General Radio Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Ward Leonard Elec. Co.

RHEOSTATS
General Radio Company
Ward Leonard Elec. Co.

SACCHARIMETERS
Taylor Instrument Cos.

SALINITY INDICATORS

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Thwing Instrument Co.

Differential
Thwing Instrument Co.

SEISMOGRAPHS

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Bristol Company
Roller-Smith Co.

SHUNTS
Esterline-Angus Co.
General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

SIGNALING DEVICES—Automatic
Bristol Co.
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.

SMOKE ALARMS
Weston Elec. Inst. Corp.

SPECIAL COILS
Ward Leonard Elec. Co.

SPECIAL ELECTRICAL INSTRUMENTS
Bristol Company
Brown Instrument Co.
General Electric Co.
General Radio Co.
Kurman Electric Co.
Pioneer Instrument Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Thwing Instrument Co.
Weston Elec. Inst. Corp.

SPECIAL INSTRUMENTS
Roller-Smith Co.
Thwing Instrument Co.

SPECTROGRAPHS
Bausch & Lomb Opt. Co.

SPECTROMETERS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

SPECTROPHOTOMETERS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

SPECTROSCOPES
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

SPEED INDICATORS
See Tachometers

SPEED RECORDERS
Bristol Company
Brown Instrument Co.
Thwing Instrument Co.

SPEED REGULATORS
Ward Leonard Elec. Co.

STANDARD CELLS
Weston Elec. Inst. Corp.

STOP WATCHES

STRAIN GAGES
General Electric Co.

STROBOSCOPES
General Radio Co.

SUNSHINE RECORDERS
Taylor Instrument Cos.

SURGE INDICATORS & RECORDERS
General Electric Co.

SYNCHRONOSCOPES
Weston Elec. Inst. Corp.
Roller-Smith Co.

SYNCHRONIZATION FORKS
Electrical
General Radio Co.

SYNCHRONOUS MOTORS
General Electric Co.
Pioneer Instrument Co.

TACHOMETERS
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Roller-Smith Co.
Thwing Instrument Co.
Weston Elec. Inst. Corp.

TACHOSCOPES
Brown Instrument Co.

TELEMETERS—See Remote Metering

TELESCOPES
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Gaertner Scientific Corp.

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Thwing Instrument Co.

Fatigue

Impact

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Hardness

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Kurman Electric Co.

Oil & Bearing

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Thwing Instrument Co.

Penetration
Thwing Instrument Co.

Portable—Tensile—Compression

Sheet Metal

Stiffness & Bending
Thwing Instrument Co.

Stretch
Thwing Instrument Co.

Tearing
Thwing Instrument Co.

Tensile (very light load)
Thwing Instrument Co.

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General Electric Co.

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General Radio Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Wilbin Instrument Co.

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General Radio Company
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

THERMOPILES

THERMOMETERS
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Bristol Company
Brown Instrument Co.

Gas Filled
Foxboro Co.
Taylor Inst. Companies

Mechanical
Brown Instrument Co.
Foxboro Co.

Mercurial
Bristol Company
Taylor Instrument Cos.

Resistance
Brown Instrument Co.
Foxboro Co.
Thwing Instrument Co.

Vapor-Tension
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Inst. Companies

Wet & Dry Bulb
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.

TIME SWITCHES
General Electric Co.

TIMERS
Bawson Elec. Inst. Co.

TIMING DEVICES
General Electric Co.

TORSIOGRAPH

TOTALIZING INSTRUMENTS
American Meter Co.
General Electric Co.

TOTALIZING RELAYS
Electric
General Electric Co.

TRANSFORMATION POINT RECORDERS
Brown Instrument Co.

TRANSFORMERS (Instrument)
General Electric Co.
General Radio Co.
Roller-Smith Co.
Weston Elec. Inst., Corp.

TRANSITS
Astronomical
Gaertner Scientific Corp.

Pocket
Taylor Instrument Cos.

TUNING FORKS—
Electrically Driven
General Electric Co.
General Radio Co.
Gaertner Scientific Corp.

TURBIDIMETERS
Bausch & Lomb Opt. Co.

U-TUBE MANOMETERS
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Brown Instrument Co.
Taylor Instrument Cos.

VACUUM RECORDERS
Bailey Meter Co.
George Sidney Binckley
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

VACUUM TUBE BRIDGES
General Radio Company

VACUUM TUBE RELAYS
Burgess Labs., Inc., C. F.

VACUUM TUBE VOLTMETERS
General Electric Co.
General Radio Co.
Rawson Elec. Inst. Co.

Electrically Operated
Bristol Company
Brown Instrument Co.
General Electric Co.
Taylor Instrument Cos.
Wilbin Instrument Co.

Motor Operated
Bristol Co.
Wilbin Instrument Co.

Pressure Relief
American Meter Co.

Proportional Air-Gas
American Meter Co.

Reducing
Bailey Meter Co.
Taylor Instrument Cos.

Regulating
American Meter Co.
Bailey Meter Co.
Bristol Co.
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Wilbin Instrument Co.

VENTURI METERS
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.

VIBROGRAPHS

VIBROSCOPES

VISCOSIMETERS
George Sidney Binckley
Taylor Inst. Companies

VOLTAGE DIVIDERS
General Radio Co.
Ward Leonard Elec. Co.

VOLT-AMMETERS
General Electric Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

VOLTMETERS
Electrostatic
General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.

Indicating
General Electric Co.
General Radio Co.
Rawson Elec. Instru. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

Recording
Bristol Company
General Electric Co.
Roller-Smith Co.

Thermionic Rectifier
General Radio Co.

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Mercury-in-glass and Bimetal; Control to 0.02° C.
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Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Wilbin Instrument Co.

THERMOSTATIC BIMETAL
W. M. Chace Valve Co.

TIME INDICATORS

TIME METERS
General Electric Co.
Weston Elec. Inst. Corp.

TIME OPERATION RECORDERS
Bristol Company
Foxboro Co.

TIME RECORDERS
Bristol Company
Brown Instrument Co.
Foxboro Co.

VALVES
Automatic Shut-Off
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Wilbin Instrument Co.

Back Pressure
American Meter Co.

Balanced
Bailey Meter Co.
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

Blow-off
American Meter Co.

Diaphragm
Bristol Company
Foxboro Co.
Taylor Instrument Cos.

Differential
American Meter Co.

WATER METERS
Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.

WATTHOUR METERS
General Electric Co.

WATTMETERS
Indicating
General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

Recording
Bristol Company
General Electric Co.
Roller-Smith Co.

WAVEMETERS
General Radio Co.

X-RAY SPECTROMETERS
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

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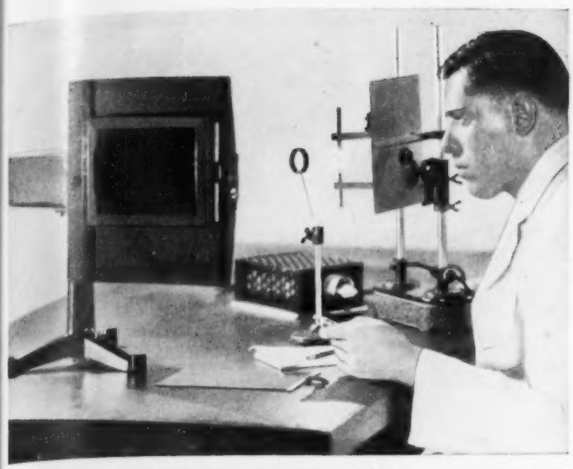
E. A. Sipp, until recently Manager of the Lighting Div. of Pyle-National Co., has joined the management of Burgess Battery Co. and C. F. Burgess Laboratories, Inc.

The 19,000 sq. ft. addition to the W. M. Chace Valve Co. plant (*Instruments*, June 1934, page 108) is completed, and the firm's facilities expanded.

WANTED—Road salesman experienced in selling laboratory apparatus. Box LF, care *Instruments*.

Seven engineers have formed the Consulting and Research Association, with office at 823 Franklin Avenue, Wilkinsburg, Pa. Its purpose is to supply consulting, research and development service to industry in fields including air conditioning, heat generation and transmission, refrigeration, properties of materials, electronic tube applications, electric circuits, oscillographs, radiographs, circuit interruption and protection, vibration analysis, plant surveys, etc.

Although its plant capacity was increased 50% only three years ago, The Meriam Co., Cleveland, again plans an increase. The new building is needed for gas and oil engine rebuilding, permitting entire present space to be used for the welding division and for the manufacture of flow and pressure instruments.



Above: The B & L New Small Littrow Spectrograph

Right: The New Density Comparator

Two new instruments for Spectrographic Analysis

Ease, speed, precision and economy are now, more than ever before, characteristic of spectrographic analysis. This increased efficiency is the result of two new B & L instruments.

THE DENSITY COMPARATOR

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THE SMALL LITTROW SPECTROGRAPH

This B & L Small Littrow Spectrograph provides for you, a simply designed, sturdy, low cost instrument for the analysis of absorption and similar spectra.

Its many applications answer long felt needs in both industry and education. Its wavelength range of 2100 to 7000 λ dispersed over 6" affords a long spectrum which permits easier reading with greater accuracy. The plate carrier will hold for scanning any standard size plate used in spectrographs.

Complete application and construction data on both of the above instruments will gladly be sent on request.

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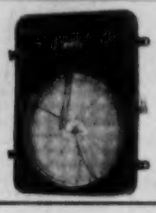

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